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DIRECT LIQUEFACTION PROOF-OF-CONCEPT PROGRAM
Hydrocarbon Technologies, Inc., Lawrenceville, N.J.

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FINAL

Topical Report
Bench Run 03 (227-93)

Work Performed Under Contract No. AC22-92PC92148

For

U.S. Department of Energy
Pittsburgh Energy Technology Center

By

Hydrocarbon Technologies Inc., Lawrenceville, NJ,

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ABSTRACT

This report presents the results of bench-scale work, Bench Run PB-03, conducted under the DOE Proof of Concept - Bench Option Program in direct coal liquefaction at Hydrocarbon Technologies, Inc. in Lawrenceville, New Jersey. The Bench Run PB-03 was the third of the nine runs planned in the POC Bench Option Contract between the U.S. DOE and Hydrocarbon Technologies, Inc. The Bench Run PB-03 had multiple goals. These included the evaluation of the effects of dispersed slurry catalyst loadings and types on the performance of two-stage direct coal liquefaction, the effect of HTI's new iron catalyst, modified with phosphorous, and the evaluation of the effect of recycle solvent hydrotreatment on the overall process performance. PB-03 employed a close-coupled (no interstage separator) configuration of hydroconversion reactors. Other features of PB-03 included the use of an in-line fixed bed hydrotreater for the net product.

No significant effects on process performance was found by changing the loadings of iron and molybdenum in the ranges of 1000-5000 ppm for iron and 50-100 ppm for molybdenum. However, the modification of HTI's iron-based gel catalyst with 100 ppm of phosphorous improved the process performance significantly. A newly tested Mo-Carbon dispersed catalyst was not found to be any better than Molyvan-A, which was used during all but one condition of PB-03. Hydrotreatment of part of the recycle solvent was found to have a positive influence on the overall performance.

EXECUTIVE SUMMARY

The Bench Run PB-03 was the third of the nine runs planned in the POC Bench Option Contract between the U.S. DOE and Hydrocarbon Technologies, Inc. The primary goal of this bench run was to evaluate the effects of type and amount of dispersed slurry catalyst used and also of the hydrotreatment of the recycle solvent on the overall process performance during direct liquefaction of a sub-bituminous coal. The entire bench run was conducted during a 32 day long continuous operation, spanning over nine operating conditions. The first four operating conditions studied the effect of iron and molybdenum dispersed catalyst loadings on process performance in a 2 x 2 test matrix; the concentration of iron catalyst was varied from 5000 to 1000 ppm at two molybdneum loadings, namely 50 and 100 ppm relative to feed coal. The variations in the dispersed catalyst loadings affected the coal and resid conversions only slightly while the light distillate yields were affected more significantly. During the next two conditions, 5 & 6, two new catalysts were investigated. Condition 5 employed HTI's iron-gel catalyst, modified with phosphorous, while condition 6 employed a molybdenum-carbon catalyst, made in a manner similar to what is known for Exxon's M-Coke catalyst. A significant positive impact on the overall process performance was obtained with the phosphorous-modified HTI's iron catalyst; the Mo-carbon catalyst, under the conditions of this test, was at best similar to the Molyvan-A precursor in terms of process performance.

The last three run conditions, 7 through 9, studied the impact of hydrotreating part of the recycle oil upon the overall process performance. It is believed that upon the catalytic hydrotreatment of highly aromatic recycle oil, the resulting product oil contains hydroaromatic compounds, known to be efficient H-transfer agents. In the interest of time and simplicity of continuous bench-scale operation, it was decided that an L-814 oil, which is a mixture of coal-derived material with mildly hydrotreated FCC decant oil, be used as a part of the recycle oil during these three conditions. This oil was first separated into a residuum-rich fraction (VSB) and a residuum-free fraction (VSOH) by vacuum distillation. The VSOH stream was hydrotreated in a fixed-bed catalytic reactor at 379°C at an LHSV of about 2.2 h^{-1}. During condition 7, the unhydrotreated VSOH was used in the recycle oil stream to establish a base-line for comparisons. During conditions 8 and 9, hydrotreated VSOH was used in the recycle oil stream; the operating severity was increased during condition 9. All three conditions also employed the residuum-rich VSB stream, derived from L-814, in order to maintain a total resid content of recycle oil around 30 w%. A definite improvement

in the overall process performance was obtained with the hydrotreated VSOH in the recycle stream. During the last three conditions, the catalyst loading was at 1000 ppm for iron and 100 ppm for molybdneum with fresh feed. A high coal space velocity of about 800-880 kg/h/m^3 reactor was employed throughout the entire run.

The following were the highlights of bench-run PB-03:

- The effect of changing iron and molybdenum catalyst loadings, between 1000-5000 ppm and 50-100 ppm respectively, was only significant in case of the C_4-524°C distillate yield and naphtha (lightest cut) formation; no noticeable effect was seen on either coal or residuum conversion.

- The modification of HTI's iron-based GelCat™ with 100 ppm of phosphorous improved process performance significantly; distillate yields and resid conversions increased by about 4 w% each, while coal conversion increased by one weight percent.

- Mo-carbon catalyst, made similar to M-Coke catalyst, was at best, as good as Molyvan-A.

- In general, net chemical hydrogen consumption was on the low side for PB-03, probably because no supported catalyst was used and space velocities were also very high. As a result, even though the in-line hydrotreated SOH product (IBP-400°C) had a high hydrogen content (1.8-1.9 H/C ratio), the unhydrotreated product which is the part of PFL that is not recycled had a very low hydrogen content (0.8-0.9 H/C ratio) and a high preasphaltene content (12-15 w% of whole PFL) which rendered the pressure filtrations extremely difficult.

- The hydrotreatment of part of the recycle oil had a positive influence; the resid conversion and distillate yields increased upon replacing part of the recycle solvent stream with a hydrotreated material.

BACKGROUND, OBJECTIVE, AND SCOPE OF WORK

The POC Bench Option Project (PB-Series) is geared to evaluate different novel processing concepts in catalytic coal liquefaction and coprocessing of organic wastes such as plastics, heavy resids, waste oils, and ligno-cellulose wastes with coal. The long-term performance data at the bench scale of operations (30 kg/day) will be used eventually to complement the larger scale process demonstration "Proof-of-Concept" studies for the U.S. DOE. The new ideas being explored in this program include using novel dispersed slurry catalysts, combinations of dispersed and supported catalysts (hybrid mode), coprocessing of coal with waste plastics, low quality resids, auto-fluff, waste oils, and ligno-cellulosic wastes, etc. As the POC Bench Option Program followed a recently completed Catalytic Multi-Stage Liquefaction (CMSL) Project, one of the primary objectives of the third bench run, PB-03, was to investigate the impact of varying dispersed catalyst loadings on the direct liquefaction of subbituminous Black Thunder mine coal using dispersed catalysts only in hydroconversion reactors.

Bench Run PB-03 was carried out for 32 operating days, spanning nine process conditions, to evaluate the effects of varying levels of iron and molybdenum dispersed slurry catalyst loadings, in an all-dispersed catalyst reaction mode with subbituminous Black Thunder Mine coal. The technical objectives were:

- To examine the effects of varying the loadings of iron and molybdenum catalyst (within the range permissible for catalyst usage on a disposable basis) under identical process severity.

- To examine the beneficial effects, of using an improved, phosphorous-modified HTI iron slurry catalyst.

- To determine the effect of using a "coked" molybdenum-containing dispersed catalyst for comparison with other new and improved dispersed catalysts.

- To determine the effects of using hydrotreated vacuum still overheads as part of the process recycle stream on the overall process performance.

Thre Run Plan for PB-03 is shown in Table 1. As shown in the Run Plan, the first four Run Conditions were designed to study the dispersed catalyst loading effects on process performance; two loadings of each iron and molybdenum were studied separately. These were 50 and 100 ppm for molybdenum (used as Molyvan-A) and 1000 and 5000 ppm for iron (used in the form of HTI's GelCat^{TM}). The next two Conditions, 5 and 6 evaluated the effects of two new dispersed catalysts, one iron-based, and another molybdenum-based. Condition 5 employed HTI's new phosphorous-modified iron gel catalyst (with Molyvan-A) while Condition 6 employed a specially "coked" molybdenum-containing precursor (with HTI's gel catalyst with no phosphorous added to it). The last three Run Conditions, 7 through 9 were designed to study the effect of replacing part of the process recycle solvent with a hydrotreated VGO material and also the effect of process severity on the performance.

SYSTEM CONFIGURATION

Bench Run PB-03 involved two equal-volume, back-mixed reactors with internal re-circulation. HTI's Unit 227 was used in this run. Coal, recycle solvent, and dispersed catalyst were introduced through the feed system of Unit 227. The second stage hot separator (O-1) overheads were sent directly to the in-line hydrotreater. A slurry product was removed from the bottom of the hot separator. An off-line pressure filtration unit was used to recover a solid-free liquid (recycle solvent) from the slurry product. The overall configuration of the bench unit and accessories put together for PB-03 is displayed in *Figure 1*.

MATERIALS USED

Feed Coal

Wyoming Black Thunder mine coal, the same coal that was employed in PDU 260-005 operations, was used for PB-03 (227-93) Bench Run. The detailed analysis of the coal is shown in Table 2.

Start-up/Make-up Oil

A mixture of coal- and petroleum-derived oil, L-814, was used as start-up/make-up oil during PB-03. The analysis is shown in Table 3.

Catalysts

Hydrotreater:	Criterion C-411 Trilobe (HRI-6135)
K-1/K-2:	Dispersed iron and molybdenum catalysts.

INTERSTAGE (Reactor K-1) SLURRY SAMPLES

Eight interstage (reactor K-1) slurry samples were planned, one each for the Conditions 2, 3, 4, 5, 6, 7, 8, and 9 were collected. These samples were taken immediately after the completion of each of the indicated work-up periods.

EXTERNAL SAMPLES

Samples of feed materials and a number of different product streams, such as SOH, PFL, PFS, and K-1 slurry, were collected from the run operation for detailed analyses and characterization by Consol, Inc. These samples are listed in Table 4.

SUMMARY OF OPERATIONS

Unit Modification and Configuration

For Run PB-03, 227 Unit was set up to process subbituminous coal using two close-coupled 2000-cc reactor stages. Neither stages contained any supported catalyst, but employed slurry catalysts mixed with the feed. This run also included the in-line hydrotreater (except in Condition 3) and a reactor preheater coil.

Figure 1, Drawing 227SF025, is a simplified flow diagram of 227 Unit for this run. Six-hour blends of feed slurry were prepared in a separate mix tank (P-7), transferred to the feed tank (P-2), and pumped to the backmixed K-1 reactor via a short-residence-time (approximately 5 minutes) preheater coil. The effluent from K-1 was sent to the second stage back-mixed reactor (K-2). The products from K-2 were separated using a hot separator (O-1). The O-1 bottoms were depressurized and withdrawn from the bottoms receiver (O-6). Overheads from O-1 flowed through the in-line hydrotreater (K-3) (except in Condition 3) and then through a cold separator (O-2). The separator bottoms from O-6 were sent to a pressure filter. Generally, the filtered liquids provided the liquid for slurrying the coal feed. In Conditions 7 through 9 hydrotreated and unhydrotreated oils, previously prepared, provided the vehicle for the feed coal.

Dispersed Catalyst Preparation

The iron catalyst (L-862, L-879, L-871, L-880, and L-878) and phosphate-modified iron catalyst (L-870) were prepared by a method outlined in a U.S. Patent 4, 434, 318, to Exxon. The molybdenum-carbon catalyst (used in Condition 6) was prepared by heating 4874 g Hondo vacuum bottoms (HTI-6272) 524 °C+ with 1405 g tert-nonylpolysulfide (TNPS) and 357 g Molyvan-A in an inert atmosphere. The mixture was heated at 38°C/hr, with agitation, in an 8-inch diameter vessel that utilized an electric heater, temperature controller, N_2-feed, back-pressure control, and knockout vessel. As the temperature approached the 427°C hold and the reaction rate increased, the temperature fluctuated, but then stabilized. The agitator continued running during the one hour at 427°C. As much as 2252 g of overheads were collected, and 2901 g of coked material were removed from the reactor. The coked material was ground to -70 mesh, yielding 2872 g of the molybdenum-carbon catalyst (L-884). This catalyst precursor contained 15.2 % ash and 12 % molybdenum.

L-814 Distillation and Hydrotreated VSOH Preparation

Conditions 7, 8, and 9 of Run PB-03 required hydrotreated and unhydrotreated distillate and resid for the feed slurry oil. These materials were prepared from L-814 (resid-containing heavy gas oil) using a 12-liter batch vacuum still and the 254 Unit as the hydrotreater.

The vacuum distillations yielded 195 kg of 454°C- VSOs plus knockouts (L-883) and 119 kg of 454°C VSBs (L-885). The D-1160 distillation and elemental analyses for the L-883 are shown in Table 5. 118 kg of the L-883 were hydrotreated in the upflow 254 Unit using presulfided Criterion C-411 (HTI-6292) catalyst. By using both "A" and "B" sides of this unit, each with 253 cc of catalyst, a total of 1260 gm/hr could be processed at a space velocity of 2.5 kg/l/hr. The operating conditions were:

Temperature:	379°C
Pressure:	2200 psig H_2
Oil Feed Rate:	630 g/h each reactor
Hydrogen Flow:	23.3 SCFH each reactor

The unit was operated for 101 hours to produce the necessary amount of product.

119 kg of hydrotreated liquid product from the O-3 and O-7 vessels (L-886) were collected. As shown in Table 5, the hydrogen content increased from 9.75% to 11.21%, the gravity increased from 10.0 to 17.0 °API, and the amount of 343°C-minus material increased from 15.4 to 29.8 W%.

Run Conditions

Run PB-03 included nine different conditions. The primary variables were the amount and type of dispersed iron and molybdenum catalyst and the use of hydrotreated and unhydrotreated distillate is a component of the feed vehicle. The amount of coal feed remained constant at 1832 g/h, and the recycle oil remained constant at 1832 g/h. The reactor temperatures were 440 °C (K-1) and 449 °C (K-2) throughout the run.

Startup

Startup consisted of establishing the proper flows of oil and gas, presulfiding the catalyst in the hydrotreater, setting vessel temperatures, testing the first stage sample system, and increasing the reactor temperatures to 413°C. Filtered L-814, heavy gas oil, was used as a startup oil for this run. The recycle material generated during the reactor heat-up period was used to slurry the coal at the beginning of Period 1. The startup proceeded without interruption.

Condition 1 (Periods 1 through 5)

Period 1 started with the introduction of coal feed at 0400 hours March 3, 1996. (Each 24 hour period started and ended at 0400 hours.) The feed rate and reactor temperatures were gradually increased, reaching full coal rate at 1800 hours Period 1 and run temperatures of 440°C (K-1) and 449°C (K-2) at 0800 hours Period 2.

By the end of Period 1 the separator bottoms were already very viscous, and the pressure filtrations required 2 1/2 hours for a 2-hour accumulation of separator bottoms. In Period 2A the hot separator (O-1) temperature was decreased from 343°C to 329°C to make the separator bottoms a little lighter. Also, a 100 µm screen was used on one of the filters. The screen passed the filtrate significantly faster, and higher temperatures and pressures could be used, but some solids did pass through the screen. More solids remained in the filtrate when the filter paper was used, because the filter paper was broken when break-through was not attained after several hours. L-814 makeup oil was added when sufficient PFL was not available in Period 2B, but in Periods 3B and 4 separator bottoms were substituted for 733 g of PFL in the recycle. For all of Period 5, the recycle was again entirely PFL; sufficient solids removal was obtained by filtering for 3 hours, then breaking the filter paper. Typically, there were about 9% solids in the PFL.

The K-1 bottom electric resistance winding on K-1 became inoperative, but there was no significant effect on the reactor temperature profile. Also, the O-1 level became erratic, causing the back-pressure to drop as much as 120 psi. The level control improved after the O-1 level was increased. The hydrogen feed was reduced for about 15 minutes after the #2 hydrogen compressor was taken off line. During this interval the hydrogen flow averaged 0%, 25%, and 35% of the specified flow to K-1 feed, K-1 ebullation, and K-2, respectively.

Condition 2 (Periods 6 through 8)

In Condition 2 the feed rate of Molyvan A was decreased from 0.6 g/h to 0.3 g/h. The recycled PFL continued to include some solids. The filtrations were started every 2 hours and terminated after about 3 hours, allowing the remaining filter feed to pass into the PFL. Except for very short feed pump outages, operations were smooth in Condition 2. The feed slurry viscosity increased from 2000 cp at 153°C to 5000 cp at 179°C. A 492 gm first stage sample was successfully obtained.

Condition 3 (Periods 9 through 11)

In Condition 3 the feed rate of the iron catalyst was decreased from 130 g/h to 26 g/h. The hydrotreater was bypassed during Condition 3.

The feed slurry viscosity established a consistent trend. Typically it would increase from 4000 cp to 7000 cp during the six hours between charges. The feed slurry temperature was varied between 174°C and 185°C. Lower temperatures caused less volatilization from P-2 and P-7, from which the collected condensed oil vapors averaged 1.5 W% of dry coal, but higher temperatures helped decrease these relatively high viscosities. Corresponding to this viscosity pattern, the overall pressure drop also increased during the six hours between charges, typically from 15 to 30 psi. There were three very brief feed pump stoppages, and the feed slurry circulation was lost once, requiring flushing the lines with L-814 oil. A 550 g first stage sample was successfully obtained.

Condition 4 (Periods 12 through 15)

In Condition 4 the feed rate of Molyvan A was increased from 0.3 g/h to 0.6 g/h. The hydrotreater was put back on line. There were brief problems with the K-1 buffer pumps. A restriction had to be removed from the discharge and drain of the right-side pump. A 540 g first stage sample was successfully obtained.

Condition 5 (Periods 16 through 19)

In Condition 5 phosphate-modified iron catalyst (L-870) replaced the unmodified catalyst at the same total rate. At the beginning of Period 16, the J-1 charge pump stopped pumping. After 25 minutes the backup pump, J-2, also stopped pumping, and unit flows were sustained with only the buffer pumps until new checks were

installed in J-1. Again in Period 18 the other charge pump had to be put on line, and the pump inlet line and checks were cleaned. The suction to the P-7 circulating pump plugged in Period 19, causing a one-hour delay in the slurry transfer to P-2. A 479 g first stage sample was successfully obtained.

Condition 6 (Periods 20 through 23)

In Condition 6 Mo-Carbon catalyst (L-884) at 1.2 g/h replaced the Molyvan-A catalyst. The backup charge pump had to be put on line three times in Period 20, but later occasional feed stoppages were corrected without changing pumps. L-814 oil was used to purge the circulation line when necessary. A 648 g first stage sample was successfully obtained.

Condition 7 (Periods 24 through 26)

In Condition 7 the molybdenum catalyst was changed back to Molyvan A at 0.6 gm/hr. The feed composition was changed to include unhydrotreated 454°C- from L-814 (L-883) at 604 gm/hr. The same total recycle rate was maintained with 848 g/h PFL and 380 g/h 454°C+ L-814 (L-885). With the lighter feed oil, the slurry viscosity decreased from 6000-9000 cp to 2000-2500 cp at 177°C and most of the filtrations went to completion in 2 to 3 hours. Both the O-1 and O-2 level control valves had to be replaced because they were passing too much material.

In Period 25 much of the charge of P-7 was lost when it boiled over. Apparently the wet coal had remained unmixed when it was mistakenly added before circulation was started, and then heated too fast when circulation was started. A 1073 gm first stage sample was successfully obtained.

Condition 8 (Periods 27 through 29)

In Condition 8 hydrotreated 454°C- from L-814 (L-886) at 604 g/h replaced the L-883 (unhydrotreated). All other feed rates remained the same. Operations were very smooth. A 601 g first stage sample was successfully obtained.

Condition 9 (Periods 30 through 32)

In Condition 9 the K-1 and K-2 temperatures were increased from 440 to 450°C and 449 to 460°C, respectively. This change was completed by 2400 hours. Slurry feed was out for about one hour. The circulation lines were flushed with L-814, and extra

buffer oil was fed to K-1 until slurry feed was restored. A 463 g first stage sample was successfully obtained.

On-Line Time Summary

The chronology of the operations for Run 227-93 is listed in Table 6 along with a summary of the total time in startup, run, shutdown, and down modes. Unit 227 operated continuously for 854 hours for an on-line efficiency of 100 %.

Shutdown and Inspection

Shutdown commenced at the end of Period 32 (0400 hours April 4, 1996). It went very smoothly. All of the process equipment was in order; only routine maintenance was required.

OPERATING CONDITIONS AND MATERIAL RECOVERY BALANCES

The overall bench run operations were smooth and without any major issues or problems. An average material recovery balance (the daily material balance summary is attached in the Appendix) of about 100.4 W% was obtained (*Figure 3*) for the entire Bench Run PB-03. The operating summary and the Process performance of individual periods during PB-03 are shown in *Tables 7a and 7b. Figure 2* shows the operating conditions during PB-03 in terms of feed space velocities and reactor temperatures. As shown in *Figure 2*, the reactor temperatures during Conditions 1 through 8 were uniform while they were increased during Condition 9.

PROCESS PERFORMANCE RESULTS

Conversions and yields, process performance, and product quality for PB-03 are addressed in this section. Calculation of daily material recovery balances, coal conversions, normalized product yields, and other process performance-related indicators was carried out using programs available in the CTSL database (some programs were also modified as per the requirement of the process configuration for PB-03). Overall process performance during PB-03, summarized in *Tables 7a & 7b* and depicted in *Figures 4 through 15,* is discussed in detail in the following sections.

Total Coal and 524°c$^+$ Residuum Conversion

Typical coal conversions (based on the solubility of pressure filter solids in quinoline and expressed on an SO_3-free basis) obtained during equilibrated periods of PB-03 are shown in *Figure 4*. Coal conversions (W% maf feed) varied beween about 94 to 96 % maf. No significant effect on coal conversion of either dispersed catalyst concentration and type or the hydrotreatment of recycle solvent was observed. The conversion of 524°C+ residuum from coal is also plotted in *Figure 4*. Residuum conversion values varied between about 80.0 to 89.0 W% (maf feed). For most of the operating conditions, resid conversion was around 82 W% maf, although it increased to over 86 W% maf during Condition 5 which employed a phosphorous-modified HTI's dispersed iron catalyst. The highest value of resid conversion, 89 W% maf, was realized for the last condition, when overall thermal severity of the process was increased by about 25%.

C_4-524°c Distillate and 524°c+ Residuum Yields

Distillate yields and 524°C+ residuum yields are shown in *Figure 5*. Distillate yields varied between 53 and 62 W% maf. During the first six operating conditions, studying the effects of dispersed catalyst concentration and type, the highest distillate yield (over 62 W% maf) was obtained with phosphorous-modified iron catalyst in Condition 5. The distillate yield showed a good response to variation in the dispersed catalyst type and concentration. The use of a molybdenum-carbon dispersed catalyst, prepared in a manner similar to Exxon's M-coke catalyst, resulted, at best, in a similar level of performance as the molybdenum precursor Molyvan-A used during the other conditions of PB-03. Distillate yields decreased when part of the coal-derived recycle oil was replaced by L-814, an oil containing petroleum-derived material. Introduction of the hydrotreated 454°C- fraction of L-814 as part of the recycle stream increased distillate yields. Residuum yields were between 6-13 W% maf and followed a trend similar to the light distillate yields.

Distillate Yield/selectivity

Yields of distillate fractions, such as naphtha (IBP-177°C), middle distillates (177-343°C), and heavy distillates (343°C+), are shown in *Figure 6*. The numbers plotted in this Figure, converted to a selectivity basis, are shown in *Figure 7*. The light fractions, namely naphtha and mid-distillate were the highest during Condition 5 that employed a phosphorous-modified iron catalyst. Typically, between 65-85 % of the distillates were in the IBP-343°C boiling range. Naphtha yields varied beteen 10-23 W% while the light distillate yields varied between 20-30 W%. The heavy distillate fraction was the lowest during the last run condition, which operated at a higher thermal severity than the rest of the run conditions.

Hydrogen Consumption and Light Gas (C_1-c_3) Yield

Hydrogen consumption *(Figure 8)* based on maf coal varied between 3.3 to 6.7 W%. In general, chemical hydrogen consumption during PB-03 tended to be on the low side, primarily because no supported catalyst was used and space velocities were high, thus operating severity was on the low side. It was clearly evident from Conditions 2, 3, and 4 that, when the in-line HTU is by-passed, total hydrogen consumption goes down by as much as 25 %. This means that in all dispersed catalyst multistage coal liquefaction with in line hydrotreating of light distillates, roughly one quarter of the total hydrogen consumption occurs across the hydrotreater. As a result, the net distillates, IBP-400°C material, leaves the process

with a high hydrogen content of about 13-14 W%, while the 400°C+ heavy material (PFL and PFC) has a low hydrogen content, in the range of 3.5-7 W%. For the first six conditions, the hydrogen consumption was highest during Condition 5, employing the phosphorous-modified iron catalyst. The use of hydrotreated recycle solvent resulted in a slight increase in hydrogen consumption; the increase in reaction severity during Condition 9 resulted in higher hydrogen consumption in part as a result of an increase in light gas yield.

Hydrogen Utilization

Hydrogen utilization during coal conversion is characterized by two indicators: hydrogen efficiency and C_1-C_3 gas selectivity. The former is defined as the amount (weight) of C_4-524°C distillate obtained per unit weight of hydrogen consumed, while the latter is the amount (weight) of light hydrocarbon gases produced per unit weight of distillates. As shown in *Figure 9*, hydrogen efficiency varied between about 9 to 17 kg distillates per kg hydrogen. The lowest hydrogen efficiency of 9 kg/kg was obtained when the reaction severity was increased during Condition 9, thereby producing more light gases. Similarly, the C_1-C_3 gas selectivity was on the high side during the last three conditions when part of the recycle oil consisted of fractions of L-814.

PRODUCT QUALITY

Product fractions (product gases, SOH, PFL, and PFS) from Work-up Periods 5, 8, 11, 15, 19, 23, 26, 29, and 32 were analyzed in detail for their composition. These analyses are listed in Tables 8 through 14.

Separator Overhead Product (SOH)

The SOH oil stream represents the net light distillate (IBP-343°C) from PB-03. While the hydrotreater unit was on-line during the run (all the operating days except for Periods 9 through 11), the only major distillate stream out of the unit was the SOH stream, as the O-1 hot separator overheads, ASOH (when the atmospheric still was on-line), and unit knockouts were being fed directly to the hydrotreater. The properties of SOH oil for the work-up periods are shown in *Table 8*. The SOH oils had a typical boiling range of 50-400°C. The API gravities were high (> 35) and H/C atomic ratios were also high (> 1.80), especially during the operating periods when the HTU was online. Condition 3, when the in-line HTU was by-passed, resulted in much poorer quality SOH oil; the API gravity plummeted to 24, and the H/C ratio decreased to only 1.53. The nitrogen and sulfur contents also increased significantly, as shown in Figure 10. The lightest naphtha fraction of the SOH oil was, in general, around 40 W%, although it dropped to only 23 W% during Condition 3. The quality of SOH process distillates, in terms of heteroatoms content and H/C ratios, is depicted in *Figures 10 and 11.* It suggests that the operating conditions of the HTU are severe enough to cause significant cracking.

Pressure Filter Liquid (PFL) and Pressure Filter Solids (PFS)

The separator bottoms go through pressure filtrations for separation of solids from heavy liquid product and recycle oil. The oil, called pressure filter liquid (PFL), usually boils above 343°C and contains some unreacted heavy residuum material. The pressure filter operation did not proceed smoothly during bench run PB-03. In almost all cases, the pressure filter papers had to be broken, since even after four hours at pressure (110 psig) and temperature (around 240°C), the filtrations were not completed. As a result, the pressure filter liquid typically ended up containing about 10-12 W% solids. Thus, some dispersed catalyst was also getting recycled through the addition of PFL to the feed slurry.

The solids from filtration, PFS, are oil-containing solids, normally extracted with toluene for oil recovery and the oil-free solids are then used for determining the

extent of coal or total feed conversion based upon the solubility of the PFS material in a solvent such as quinoline. Analyses of the PFL and PFS streams (before toluene-extraction) from PB-03 are listed in Tables 9 and 10. The PFL API gravity was low (-ve) for all the conditions, while the resid content of the PFL was around 37 W% during the first six conditions and decreased to below 30 W% during the last three conditions when a part of the recycle solvent was replaced by oil fractions derived from L-814. In general, the asphaltene and the preasphaltene contents of the PFL were on the high side (Figure 12); the H/C ratio was only 1.00 or lower, indicating that in the absence of supported catalyst in the hydroconversion reactors, the 400°C+ material (which constitutes the PFL) exits the reaction system with a low extent of hydrogenation. In this situation, a mild hydrotreatment of the hydrogen-depleted PFL recycle oil would be expected to benefit the process substantially by improving the hydroaromatic character of PFL.

As shown in Table 10, the H/C ratios of the pressure filter solids (sampled and analyzed prior to extraction with toluene) were high (around 0.85) due to oil retention. Coal conversion based upon quinoline insolubility of the pressure filter solids, corrected to the ash content of the feed coal, was around 95 W% maf throughout the run.

Analysis of True Boiling Point (TBP) Fractions

Of the nine work-up periods during bench run PB-03, only four were selected for carrying out a full TBP fractionation and analyses of the net process distillates. Periods 15 and 19 were chosen in order to determine whether the phosphorous modification of HTI's iron gel catalyst improved the quality of process distillates; periods 26 and 29 were chosen to see if the use of a hydrotreated solvent, as a part of the process recycle stream, had enhanced the product slate from liquefaction. The quality of the TBP fractions (Tables 11-14) was not significantly different for Periods 15 and 19; similarly, it was about the same for distillates from Periods 26 and 29. The lack of any effect of process conditions on the net distillate properties is probably because of the "finishing" job done by the in-line hydrotreating unit.

DISCUSSION OF PROCESS PERFORMANCE RESULTS

Effects of Dispersed Catalyst Type and Amount

One of the primary objectives of Bench Run PB-03 was to study the effects of loading and type of dispersed slurry catalysts. Throughout the run, different concentrations of HTI's proprietary iron-based catalysts were employed along with Molyvan-A as a molybdenum precursor. Only during Condition 5, was the iron gel catalyst, promoted with phosphorous, employed. Condition 6 used, in place of Molyvan-A, a specially made molybdenum-carbon catalyst (which was similar to Exxon's M-Coke dispersed catalyst). Catalyst concentration effects were studied during the first four run conditions in a 2 X 2 test matrix, as shown in Table 7a. Two sets of iron and molybdenum concentrations were employed. (5000 and 1000 ppm for iron and 50 and 100 ppm for molybdenum). As shown in Table 7a and Figures 13 and 14, the total coal and residuum conversions were hardly influenced by variations in dispersed catalyst loadings (through fresh catalyst additions); although distillate yield was reduced upon decreasing the catalyst loadings by over 4 W%. The quantitative effect of reducing iron from 5000 to 1000 ppm on distillate yield was similar to that of reducing molybdenum from 100 to 50 ppm.

The addition of a phosphorous-modified iron gel catalyst during Condition 5 resulted in significant improvement over Condition 4, which did not employ a phosphorous-modified iron catalyst. At about 100 ppm of phosphorous addition, the distillate yield increased by over 3 %, and residuum conversion increased by about 4 W%. The molybdenum-carbon catalyst, employed during Condition 6 in place of Molyvan-A, did not show any performance improvements; rather, process performance degraded slightly as compared with condition 4 which had employed Molyvan-A at the same molybdenum concentration.

Effects of Hydrotreatment of Recycle Solvent

During the last three conditions of bench run PB-03, an attempt was made to delineate the effect of hydrotreating part of the recycle solvent. For this purpose, an external oil, L-814, was used after it had been vacuum distilled. The VSBs from the L-814 distillation were added to the recycle solvent to maintain the total resid content of the recycle at around 30 W%. The VSOH from the L-814 distillation (454°C- material) was hydrotreated off-line using Criterion C-411 NiMo on alumina supported catalyst in a trickle-bed reactor. The hydrotreatment at 379°C at an LHSV of about

2.2 h^{-1} increased the hydrogen content of VSOH by as much as 14%. It is assumed that most of the added hydrogen increased the hydroaromatic content of L-814 VSOH material.

The hydrotreated material was used as a part of the recycle oil during conditions 8 and 9, while condition 7 employed straight VSOH from L-814 in the recycle oil. Comparison between Conditions 7 and 8 indicates a positive effect of using hydrotreated oil in the recycle. A noticeable increase on the residuum conversion and distillate yields was obtained (Table 7b and Figure 15). Overall process severity during the last condition was increased; as a result the residuum conversion and distillate yield increased along with C_1-C_3 light gas production and hydrogen consumption. In light of the results obtained here, it would be interesting to study the effect of hydrotreating the actual coal-derived recycle solvent.

TECHNO-ECONOMIC ASSESSMENT

The economic benefit of the interstage separator, as pointed out in the CMSL-run series, is in reducing the reactor vapor load, thus allowing increased throughput for a given target hydrogen partial pressure and for a given limiting gas velocity. The commercial projection for PB-1 and PB-2 results, with an interstage separator, was based on construction of maximum-sized reactors at a total liquefaction feed rate of 12,000 T/D with four parallel liquefaction trains. The target hydrogen partial pressure and the limiting superficial gas velocity values were those used in most of the design work to date, and are accepted as a "safe" design values with ebullated bed reactors and supported catalyst. The techno-economic assessment results are summarized in Tables 15 through 20.

For a constant hydrogen partial pressure value, when the interstage separator is excluded two options are readily available for meeting the safe design superficial gas velocity criterion: adding liquefaction trains and reducing capacity. As illustrated in Figure 16 for the results from PB-3 Period 19, the same reactor throughput of 12,000 Tons/Day would require roughly 7 liquefaction trains. The economic penalty of this move is over $3.00/B (10 percent) in equivalent crude oil price, as shown in Figure 17. On the other hand, throughput would have to be far below 10,000 Ton/Day, and the economic penalty is more than $1.00/B for each 1,000 Ton/Day reduction.

Comparison of successive runs affords benefits of consistency in evaluating the results. In order to keep the 12,000 Ton/Day reactor throughput for the PB-3 results in a reasonable number of liquefaction trains, it was decided to forego the superficial gas velocity limitation altogether, and assume that dispersed catalyst operation would allow a 50 percent increased allowable gas velocity. This philosophy may necessitate revisiting the PB-1 results at a later date and would certainly lower the PB-1 costs. Note that results of the PB-2 evaluation, with a hybrid catalyst system, would be unaffected by this superficial gas velocity consideration.

The "bottom line" of this evaluation is that PB-3 results, except for Period 19 with phosphorus catalyst addition, are definitely inferior to PB-1 results. Use of the interstage separator, as far as the economics are concerned, is a "must" requirement. Figure 18 shows that for the prices assumed, the economics are far more sensitive to iron rates than to Moly, for the period noted. If at all possible, Iron rates should be lowered. The overall economic summary of bench run PB-03 and its comparison with other bench runs is summarized in Table 21.

CONCLUSIONS

The following conclusions can be drawn based upon the data obtained from Bench Run PB-03:

- The effect of changing iron and molybdenum catalyst loadings, between 1000-5000 ppm and 50-100 ppm respectively, was only significant in case of the C_4-524°C distillate yield and naphtha (lightest cut) formation; no noticeable effect was seen on either coal or residuum conversion.

- The modification of HTI's iron-based GelCat™ with 100 ppm of phosphorous improved process performance significantly; distillate yields and resid conversions increased by about 4 w% each, while coal conversion increased by one weight percent.

- Mo-carbon catalyst, made similar to M-Coke catalyst, was at best, as good as Molyvan-A.

- In general, net chemical hydrogen consumption was on the low side for PB-03, probably because no supported catalyst was used and space velocities were very high. As a result, even though the in-line hydrotreated SOH product (IBP-400°C) had a high hydrogen content (1.8-1.9 H/C ratio), the unhydrotreated product which is the part of PFL that is not recycled had a very low hydrogen content (0.8-0.9 H/C ratio) and a high preasphaltene content (12-15 w% of whole PFL) which rendered the pressure filtrations extremely difficult.

- Hydrotreatment of part of the recycle oil had a positive influence; the resid conversion and distillate yields increased upon replacing part of the recycle solvent stream with a hydrotreated material.

Table 1. Run Plan for Bench Run PB-03

Condition		1	2	3	4	5	6	7***	8****	9****
Period Number		1-5	6-8	9-11	12-15	16-19	20-23	24-26	27-29	30-32
Work-Up Period		5	8	11	15	19	23	26	29	32
Dispersed Catalyst ppm:	Fresh Mo	100	50	50	100	100	100*	100	100	100
	Fresh Iron	5000	5000	1000	1000	1000**	1000	1000	1000	1000
Feed		----------Black Thunder Mine coal----------								
Recycle Ratio		----------1.0----------								
Space Velocity, kg/hr/m^3 react		800	800	800	800	800	800	800	800	800
Temperatures, °C										
	K-1	441	441	441	441	441	441	441	441	450
	K-2	449	449	449	449	449	449	449	449	460
	In-line HTU	379	379	379	379	379	379	379	379	379

*A Mo-Carbon catalyst was employed during Condition 6

** An improved HTI iron catalyst (P-modified) was used during Condition 5

***Vacuum distillates (unhydrotreated) was used in the recycle solvent

****Hydrotreated vacuum distillates was used in recycle solvent

Table 2. Analysis of Feed Black Thunder Mine Feed Coal

HTI Designation	HTI 6213
Moisture Content, W%	10.01
Proximate Analysis, W% Dry	
Volatile Matter	43.48
Fixed Carbon	50.52
Mineral Matter	6.00
Ultimate Analysis, W% Dry	
Carbon	70.12
Hydrogen	5.11
Nitrogen	0.99
Sulfur	0.35
Ash	6.19
Oxygen (Diff.)	17.24
H/C Atomic Ratio	0.875

Table 3. Analysis of Start-up/Make-up Oil

HTI Designation		Filtered L-814
API Gravity, °		0.40
ASTM D-1160 Distillation, °C		
	IBP	309
	5 V%	351
	10 V%	374
	20 V%	394
	30 V%	409
	40 V%	426
	50 V%	437
	60 V%	449
	70 V%	467
	80 V%	507
	84 V%	524
Weight Percents		
	IBP-343°C	5.47
	343-454°C	53.99
	454-524°C	22.18
	524°C$^+$	18.36
Elemental Analysis, W%		
	Carbon	88.96
	Hydrogen	8.25
	Sulfur	2.22
	Nitrogen	0.19
NMR Data		
	W% Aromatic Carbon	88.03
	W% Cyclic Hydrogen	44.36

Table 4. List of Samples Provided to Consol, Inc.

Sample Description	*Typical Amount, g*	*Periods*
Feed Slurry	250	5, 8, 11, 15, 19, 22, 26, 29, and 32
CAS Bottoms	350	5, 8, 11, 15, 19, 22, 26, 29, and 32
SOH Oil	250	5, 8, 11, 15, 19, 22, 26, 29, and 32
Pressure Filter Solids	350	5, 8, 11, 15, 19, 22, 26, 29, and 32
Pressure Filter Liquid	250	5, 8, 11, 15, 19, 22, 26, 29, and 32

Table 5. Run 254-28 FEED AND PRODUCT ANALYSES L-814 DISTILLATE AND HYDROTREATED DISTILLATE

		454°C- Distillate	Hydrotreated 454°C- Distillate
Designation		L-883	L-886
Gravity, °API		10.0	17.0
Distillation, °F			
	IBP	534	291
	5 V%	598	534
	10 V%	634	586
	20 V%	657	627
	30 V%	689	648
	40 V%	709	664
	50 V%	725	692
	60 V%	745	709
	70 V%	760	729
	80 V%	775	749
	90 V%	801	778
	95 V%	818	803
	99 V% (EP)	856	845
Elemental Analyses, W%			
	Carbon	88.21	88.27
	Hydrogen	9.75	11.21
	Nitrogen	0.16	0.07

Table 6.
RUN 227-93 OPERATIONS-STATUS-CLASSIFICATION CHRONOLOGY

Operations Classification I.D.	Start Time	Start Date	End Time	End Date	Duration, Hours
S/U	1400	3/1/96	0400	3/3	38
1-32	0400	3/3	0400	4/4	768
S/D	0400	4/4	0400	4/6	48

ON-LINE TIME AND DOWN TIME FOR RUN 227-93

Time of Initial S/U & Final S/D, Hours	Time of Intermediate S/Ds & S/Us, Hours (No. of Int. S/D-S/U Pairs)	Total On-Line Time, Hours	Down-Time, Hours	On-Line Efficiency, %
86	0 (0)	854	0	100.0

Definitions:

S/U = Startup. Time between gas flow initiation and feedstock cut-in during which unit temperatures and/or pressures are being increased.

S/D = Shutdown. Time between feedstock cut-out and liquid flow termination during which unit temperatures and/or pressures are being decreased.

Run-Periods = Time during which the unit is at run conditions and the operations is identified with a Period number.

On-Line Time = The sum of S/Us, S/Ds, and Run-Periods.

Down-Time = The time during which gases and liquids are not being charged to the unit. This is the same as the time between an intermediate shutdown and startup.

On-Line Efficiency = On-Line Time / (On-line Time + Down-Time)

Table 7a
Run PB-03: Process Performance Summary
Effect of Dispersed Catalyst Type and Amount

Feed Coal: Wyoming Black Thunder Mine Coal
Back Pressure: 2500 psig

Condition	1	2	3	4	5	6
Period Number	5	8	11	15	19	22
Hours of Run	120	192	264	360	456	528
Dispersed Catalyst Type						
Iron	HTI-Fe	HTI-Fe	HTI-Fe	HTI-Fe	HTI-Fe*	HTIFe
Molybdenum	MoV-A	MoV-A	MoV-A	MoV-A	MoVA	Mo-C
Dispersed Catalyst Amount, ppm						
Iron	5000	5000	1000	1000	1000	1000
Molybdenum	100	50	50	100	100	100
Space Velocity, kg/h/m^3 react	868	809	828	769	795	816
Temperatures, °C						
First Stage	439	441	442	441	442	442
Second Stage	448	449	450	451	451	449
Material Balance (%) (gross)	93.27	99.13	98.54	103.28	100.77	99.30
Estimated Normalized Yields, W% Ash Free Coal:						
C_1-C_3 in Gases	8.7	11.06	10.48	10.13	10.81	10.84
C_4-C_7 in Gases	5.1	3.32	3.46	6.08	8.22	6.20
IBP-177°C in Liquids	12.18	12.73	6.93	11.89	14.59	12.15
177-260°C in Liquids	9.50	9.92	12.86	10.30	12.68	9.29
260-343°C in Liquids	12.1	12.28	12.47	11.45	11.71	12.08
343-454°C in Liquids	16.46	14.59	15.37	14.11	11.47	11.65
454-524°C in Liquids	4.63	4.58	4.31	4.92	3.40	3.36
524°C+	11.94	12.7	11.89	11.7	8.97	12.83
Unconverted Feed	5.50	5.49	5.19	5.24	4.32	5.41
Water	14.27	12.48	15.61	14.05	14.71	15.15
CO	1.03	0.91	1.41	1.04	1.04	1.04
CO_2	3.31	4.13	3.16	2.98	2.86	3.51
NH_3	0.75	0.66	0.51	0.65	0.86	0.79
H_2S	-1.03	-0.63	-0.38	-0.15	-0.20	-0.1
Hydrogen Consumption	4.44	4.22	3.27	4.39	5.44	4.2
Process Performance, W% MAF Feed						
Coal Conversion	94.5	94.5	94.8	94.8	95.7	94.6
C_4-524°C Distillate Yield	60.0	57.4	55.4	58.8	62.1	54.8
524°C+ Conversion	82.4	81.6	82.7	82.9	86.6	81.4

*During Condition 5, the HTI-Fe dispersed catalyst also contained about 2W% of phosphorous, i.e., approx. 100 ppm relative to feed coal.

Table 7b
Run PB-03: Process Performance Summary
Effect of Recycle Solvent Hydroteatment*

Feed Coal: Wyoming Black Thunder Mine Coal
Back Pressure: 2500 psig
Catalysts: 1000 ppm Fe (HTI-Fe)
100 ppm Mo (Molyvan-A)

Condition	7	8	9
Period Number	26	29	32
Hours of Run	624	696	768
Vehicle Composition, W% Coal			
Process-PFL	54.6	56.1	55.8
Unhydrotreated Oil	59.7	0	0
Hydrotreated Oil	0	59.7	59.7
Space Velocity, kg/h/m^3 react	816	801	751
Temperatures, °C			
First Stage	441	442	450
Second Stage	450	450	460
Material Balance (%) (gross)	99.03	97.69	98.94
Estimated Normalized Yields, W% Ash Free Coal:			
C_1-C_3 in Gases	10.91	11.27	13.46
C_4-C_7 in Gases	5.26	5.42	7.89
IBP-177°C in Liquids	10.68	11.41	14.41
177-260°C in Liquids	12.17	14.32	20.92
260-343°C in Liquids	11.32	6.86	8.82
343-454°C in Liquids	12.85	13.95	9.98
454-524°C in Liquids	0.59	2.59	-1.45
524°C+	14.17	11.21	6.28
Unconverted Feed	5.84	6.42	4.73
Water	15.55	15.52	15.32
CO	1.08	1.11	1.18
CO_2	3.30	3.41	3.58
NH_3	0.57	0.60	0.72
H_2S	0.60	0.71	0.83
Hydrogen Consumption	4.89	5.5	6.67
Process Performance, W% MAF Feed			
Coal Conversion	94.2	93.6	95.3
C_4-524°C Distillate Yield	52.9	54.6	60.6
524°C+ Conversion	79.9	81.6	89.0

*VSOH fraction of L-814 was used as a part of recycle solvent; unhydrotreated in Condition 7 and hydrotreated in Conditions 8 and 9.

Table 8

Separator Overhead (SOH) Properties

Period	5	8	11	15	19	23	26	29	32
Gravity, °API	38.7	39.0	24.5	38.4	37.6	38.4	38.4	37.8	37.5
IBP, °C	53	52	54	49	44	54	57	51	51
FBP, °C	372	373	406	368	375	377	387	381	372
Elemental Analysis									
Carbon, W%	86.34	86.14	83.52	85.73	86.59	86.51	86.51	86.26	86.54
Hydrogen, W%	13.08	13.11	10.66	12.92	12.79	12.99	13.04	13.03	12.83
Sulfur (Antek), ppm	72.3	40.5	1141.0	74.4	108.0	102.4	99.4	62.6	70.9
Nitrogen (Antek), ppm	24.0	26.7	4657.0	64.8	98.2	62.1	54.4	39.9	47.0
H/C Ratio	1.82	1.83	1.53	1.81	1.77	1.80	1.81	1.81	1.78
ASTM D-86 Distillation, Composition, W%									
IBP-177oC	40.2	41.5	23.3	41.4	41.4	40.3	38.3	37.1	35.9
177-260oC	26.8	27.1	36.3	28.5	28.1	28.7	26.9	25.0	28.1
260-343oC	24.9	25.1	28.1	24.0	23.8	24.7	25.3	28.5	29.2
343oC+	7.0	6.3	11.4	5.2	6.0	6.1	9.0	8.6	6.8
Loss	1.1	0.0	0.9	0.9	0.7	0.2	0.5	0.8	0.0

Table 9
Pressure Filter Liquids Properties

Period	5	8	11	15	19B*	23	26	29	32
Gravity, °API	-8.0	-9.4	-10.0	-9.7	-9.5	-13.2	-4.0	-1.1	-1.2
IBP, °C	253	237	235	224	221	231	224	238	226
Elemental Analysis, W%									
Carbon	84.04	84.08	83.76	84.17	83.82	82.35	87.22	88.15	88.72
Hydrogen	7.20	7.12	6.95	6.97	6.96	6.55	7.65	8.13	7.95
Sulfur	1.09	0.945	0.870	0.574		0.653	0.894	0.611	0.575
Nitrogen	1.01	1.16	1.15	1.19	1.01	1.03	0.69	0.64	0.65
H/C Ratio	1.03	1.02	1.00	0.99	1.00	0.95	1.05	1.11	1.08
ASTM D-1160 Distillation, Composition, W%									
IBP-343oC	12.74	12.67	15.62	14.97	18.02	12.71	14.05	16.13	20.81
343-454oC	38.05	34.31	33.39	34.34	32.67	30.10	42.79	41.66	43.00
454-524oC	12.30	12.50	11.93	13.43	11.90	10.37	13.61	14.38	11.60
524oC+	36.30	39.66	38.54	36.58	36.90	46.15	29.28	27.28	24.22
Loss	0.61	0.86	0.52	0.68	0.51	0.67	0.27	0.55	0.37
Cyclohexane Insolubles	60.74	70.89	76.83	73.37	82.88	80.93	74.80	79.35	77.58
Toluene Insolubles	32.75	33.53	38.38	37.77	39.88	38.23	22.15	20.32	17.27

Table 10
Inspection of the Pressure Filter Solids (Composite Sample)

Condition	1	2	3	4	5	6	7	8	9
Period	5	8	11	15	19	23	26	29	32
Elemental Analysis, W%									
Carbon	50.86	55.40	57.73	58.19	59.14	59.89	60.43	60.79	56.73
Hydrogen	3.65	3.88	4.17	4.18	4.28	4.16	4.48	4.46	3.99
Sulfur	5.59	4.63	2.91	2.12	1.95	1.87	2.11	1.88	2.16
Nitrogen	0.64	0.77	0.82	0.83	0.67	0.68	0.49	0.51	0.44
H/C Ratio	0.86	0.84	0.87	0.86	0.87	0.83	0.89	0.88	0.84
Composition, W%									
Quinoline Insolubles	56.45	54.18	51.07	50.40	46.78	46.36	50.14	52.39	53.28
Ash (in Quinoline Filt.)	38.95	37.46	34.06	31.49	29.31	28.29	29.20	28.92	32.81
Sulfur in Ash	9.51	9.52	7.58	5.55	5.15	5.27	4.89	4.69	4.41
ASTM Ash	38.05	36.90	33.47	31.87	31.16	28.69	29.38	29.53	34.26
Sulfur in Ash	7.60	7.59	7.39	5.73	4.82	5.42	4.59	4.88	4.97
Coal Conversion, W% MAF	95.01	95.07	95.06	95.1	95.54	94.95	94.58	94.04	95.38

Table 11. Analysis of TBP Fractions: PB-03 Period 15

TBP Distillation, % IBP = 48°C

	W%
IBP-177°C	42.3
177-260°C	28.6
260-343°C	24.1
343°C+	5.0

TBP FRACTION [°C]	IBP-177	177-260	260-343	343+
API Gravity	52.7	31.9	22.2	20.1
Elemental Analysis [W%]				
Carbon	85.20	87.85	88.61	87.91
Hydrogen	14.16	12.36	11.60	11.71
Antek S, ppm	10	89	112	114
Antek N, ppm	9	68	93	137
Bromine No. [g/100g]	2.34	1.73	1.30	
Aniline Point, [°C]	40.6	31.1	29.4	
Flash Point, [°C]	<-17.8	70	127	
Pour Point, [°C]	<-62.2	<-62.2	-28	
PONA [V%] -				
Paraffins	23.72	6.83		
Olefins	0.80	1.70		
Naphthenics	69.29	60.26		
Aromatics	6.19	31.21		
Aromatics (ASTM D2549)			51.03	

Table 12. Analysis of TBP Fractions: PB-03 Period 19

TBP Distillation, % IBP = 44°C

	W%
IBP-177°C	42.1
177-260°C	28.5
260-343°C	23.4
343°C$^+$	6.0

TBP FRACTION [°C]	IBP-177	177-260	260-343	343+
API Gravity	52.6	31.0	20.8	18.2
Elemental Analysis [W%]				
Carbon	84.81	87.60	88.86	87.72
Hydrogen	14.09	12.31	11.41	11.58
Antek S, ppm	34	97	110	121
Antek N, ppm	24	87	124	139
Bromine No. [g/100g]	4.81	8.60	2.15	
Aniline Point, [°C]	42.8	26.7	24.4	
Flash Point, [°C]	<-17.8	73.3	127	
Pour Point, [°C]	<-62.2	<-62.2	-30	
PONA [V%] -				
Paraffins	25.76	7.47		
Olefins	0.80	2.10		
Naphthenics	68.41	57.19		
Aromatics	5.03	33.24		
Aromatics (ASTM D2549)			56.48	

Table 13. Analysis of TBP Fractions: PB-03 Period 26

TBP Distillation, % IBP = 57°C

	W%
IBP-177°C	38.3
177-260°C	26.9
260-343°C	25.8
343°C$^+$	9.0

TBP FRACTION [°C]	IBP-177	177-260	260-343	343+
API Gravity	52.9	33.3	22.8	20.5
Elemental Analysis [W%]				
Carbon	85.03	87.81	88.50	88.15
Hydrogen	14.10	12.79	11.89	12.03
Antek S, ppm	21	99	111	132
Antek N, ppm	14	71	99	110
Bromine No. [g/100g]	1.04	1.28	0.76	
Aniline Point, [°C]	43.9	36.1	39.4	
Flash Point, [°C]	<-17.8	71.7	104.4	
Pour Point, [°C]	<-62.2	<-62.0	-56.8	
PONA [V%] -				
Paraffins	27.97	12.92		
Olefins	0.90	1.50		
Naphthenics	65.84	56.31		
Aromatics	5.29	29.27		
Aromatics (ASTM D2549)			48.71	

Table 14. Analysis of TBP Fractions: PB-03 Period 29

TBP Distillation, % IBP = 51°C

	W%
IBP-177°C	37.2
177-260°C	24.3
260-343°C	29.6
343°C$^+$	8.9

TBP FRACTION [°C]	IBP-177	177-260	260-343	343+
API Gravity	53.4	43.2	23.2	21.1
Elemental Analysis [W%]				
Carbon	85.15	87.86	88.27	88.22
Hydrogen	14.16	12.79	12.03	12.19
Antek S, ppm	12	66	110	114
Antek N, ppm	9	43	78	108
Bromine No. [g/100g]	0.65	1.11	0.66	
Aniline Point, [°C]	42.8	35.6	40.5	
Flash Point, [°C]	<-17.8	71.1	115.5	
Pour Point, [°C]	<-62.2	<-62.0	-28.0	
PONA [V%] -				
Paraffins	27.91	12.18		
Olefins	0.90	1.90		
Naphthenics	64.89	56.78		
Aromatics	6.30	29.14		
Aromatics (ASTM D2549)			45.61	

Table 15. Material Balance for Economic Assessment

	Period 8	Period 15	Period 19	Period 26	Period 29
Feed, T/D					
Coal	12,000	12,000	120000	12,000	12,000
Oil	0	0	0	0	0
Auto Shredder Residue	0	0	0	0	0
Plastics	0	0	0	0	0
Total	12,000	12,000	12,000	12,000	12,000
Liquid Products, B/D					
Gasoline	11,736	12,033	12,951	11,802	11,660
Diesel Fuel	28,503	29,222	31,453	28,661	28,317
Total	40,239	41,255	44,404	40,463	39,977
Barrels of Products/Ton Feed	3.35	3.44	3.70	3.37	3.33
By-products					
Propane, B/D	5,908	4,537	5,012	3,946	4,061
Butane, B/D	2,122	2,235	2,509	1,973	2,014
Sulfur, T/D	55	56	56	56	56
Ammonia, T/D	75	74	98	65	68
Waste to Disposal, T/D	704	659	539	564	567

Table 16. Hydrogen Balance, Utilities Production, and Thermal Efficiency

	Period 8	Period 15	Period 19	Period 26	Period 29
Hydrogen Balance					
Hydrogen Consumption, MMSCFD					
Liquefaction	246.4	232.4	279.4	221.8	229.0
Product Upgrading	49.8	68.2	47.2	80.4	75.5
Solution & Purge Loss	18.3	18.4	20.2	20.6	21.1
Total	314.5	319.0	346.8	322.8	325.6
Hydrogen production, MMSCFD					
via Partial Oxidation	174.9	172.0	131.2	173.7	177.4
via Steam Reforming	139.6	147.0	215.6	149.1	148.2
Total	314.5	319.0	346.8	322.8	325.6
Utilities Produced or Purchased					
Power, Mw	234	227	227	227	231
Steam (600 Psig), 1000 Lb/hr	303	262	251	259	270
Cooling water, 1000 GPM	173	164	171	166	169
Purchased Natural Gas, MMMBTU/D	75.7	77.0	97.6	68.7	66.1
Raw water, 1000 Gal/D	8,372	7,771	7,169	7,849	8,050
Thermal Efficiency					
Inputs, MMMBTU/D					
Feed	291.5	291.5	291.5	291.5	291.5
Natural Gas	75.7	77.0	97.6	68.7	66.1
Total	367.2	368.5	389.1	360.2	357.6
Outputs, MMMBTU/D					
Gasoline	65.6	67.3	72.4	66.0	65.2
Diesel	165.4	169.6	182.6	166.3	164.3
Propane	22.7	17.5	19.3	15.2	15.6
Butane	9.2	9.7	10.9	8.6	8.8
Sulfur & Ammonia	1.9	1.9	2.4	1.8	1.8
Total	264.8	266.0	287.6	257.9	255.7
Thermal Efficiency, %	72.1	72.2	73.9	71.6	71.5

Table 17. Liquefaction Plant Investment Details

	Period 8	Period 15	Period 19	Period 26	Period
Major Equipment Cost, $M					
Pumps	24,996	24,913	24,862	24,636	24,595
Reactors & Hydrotreater	44,273	44,973	44,273	43,542	44,273
Fired Heaters	14,949	14,904	14,366	14,617	14,485
Exchangers	21,541	21,469	21,777	21,568	21,704
Drums	28,532	28,374	29,051	28,598	29,379
Towers	8,848	8,735	8,788	8,634	8,687
Compressors	31,972	31,086	33,768	30,344	30,853
HPU	26,062	26,033	27,785	28,140	28,574
Total	201,173	200,487	204,670	200,079	202,55
Plant Investment, $MM					
Materials & Equipment	364.5	363.2	370.8	362.5	367.0
Labor & Subcontracts	157.7	157.2	160.5	156.9	158.8
Indirects	131.2	130.8	133.5	130.5	132.1
Total Liquefaction Plant Investment, $MM	653.4	651.2	664.8	649.9	657.9

Table 18. Total Plant Investment Summary

Plant Section	Period 8	Period 15	Period 19	Period 26	Period 29
Coal Preparation	239.7	239.7	239.7	239.7	239.7
Oil Storage & Handling	0.0	0.0	0.0	0.0	0.0
Auto Shredder Residue Prep'n	0.0	0.0	0.0	0.0	0.0
Plastics Preparation	0.0	0.0	0.0	0.0	0.0
Liquefaction	653.4	651.2	664.8	649.9	657.9
Hydrogen Manufacture	279.6	283.0	302.7	285.5	287.2
Oxygen Plant	80.4	79.5	65.7	80.1	81.2
Treating	317.2	300.4	314.2	314.1	319.9
Product Upgrading	109.4	108.4	110.8	102.3	100.3
Utilities	306.2	284.7	285.3	285.5	288.9
Tankage, Waste Handling	134.5	136.6	143.3	133.4	132.2
General Offsites	211.0	211.0	211.0	211.0	211.0
Subtotal	2,331.4	2,294.5	2,337.5	2,301.5	2,318.3
Fee, Contingency	465.9	458.5	467.0	459.6	463.2
Total Plant Investment	2,797.3	2,753.0	2,804.5	2,761.1	2,781.5
$/BPD of Product	69,517	66,731	63,159	68,238	69,578

Table 19. Product Cost Calculation

	Period 8	Period 15	Period 19	Period 26	Period
Operating Costs, $MM/year					
Coal, as received ($7.00/T)	32.46	32.46	32.46	32.46	32.46
Oil ($8.00/B)	0.00	0.00	0.00	0.00	0.00
Auto Shredder Residue ($0.00/Ton)	0.00	0.00	0.00	0.00	0.00
Plastics ($0.00/Ton)	0.00	0.00	0.00	0.00	0.00
Natural gas ($2.00/MMBTU)	49.73	50.59	64.11	45.16	43.40
River Water ($2.50/Mgal)	6.88	6.38	5.89	6.45	6.61
Catalysts & Chemicals	11.98	12.23	15.80	12.35	12.36
Dispersed Catalyst	32.72	8.67	8.80	8.67	8.67
Ash disposal($5.00/T)	1.16	1.08	0.89	0.93	0.93
Labor	30.35	30.35	30.35	30.35	30.35
Maintenance	27.18	27.18	27.18	27.18	27.18
Capital-Related	414.79	409.09	417.89	409.78	412.39
Total	607.25	578.03	603.37	573.33	574.35
Byproduct credits, $MM/year					
Propane ($12.50/B)	24.26	18.63	20.58	16.21	16.67
Butane ($14.50/B)	10.11	10.64	11.95	9.40	9.59
Sulfur ($52.00/T)	0.95	0.95	0.95	0.95	0.96
Ammonia ($120.00/T)	2.95	2.91	3.85	2.55	2.68
Total	38.27	33.13	37.33	29.11	29.90
Net Product Cost, $MM/year	568.98	544.90	566.04	544.22	544.45
Net Product Cost, $/B	43.05	40.21	38.81	40.94	41.46
Crude Oil Equivalent Factor	0.863	0.850	0.844	0.853	0.856
Equivalent Crude Oil Price, $/B	**37.14**	**34.18**	**32.74**	**34.94**	**35.47**

Table 20. Breakdown of Equivalent Crude Oil Price

	Period 8	Period 15	Period 19	Period 26	Period 29
Product, B/D	40,239	41,255	44,404	40,463	39,977
Contribution to Price, $/B					
Coal	2.12	2.04	1.88	2.08	2.11
Oil	0.00	0.00	0.00	0.00	0.00
Auto Shredder Residue	0.00	0.00	0.00	0.00	0.00
Plastics	0.00	0.00	0.00	0.00	0.00
Natural Gas	3.25	3.17	3.71	2.90	2.83
Water	0.45	0.40	0.34	0.41	0.43
Dispersed Catalyst	2.14	0.54	0.51	0.56	0.56
Other Catalysts & Chemicals	0.78	0.77	0.91	0.79	0.81
Waste disposal	0.08	0.07	0.05	0.06	0.06
Labor	1.98	1.90	1.76	1.95	1.98
Maintenance	1.77	1.70	1.57	1.75	1.77
Capital Related Costs	27.07	25.67	24.17	26.31	26.87
By-product Credit	-2.50	-2.08	-2.16	-1.87	-1.95
Equivalent Crude Oil Price, $/B	**37.14**	**34.18**	**32.74**	**34.94**	**35.47**

Table 21. Comparison of Economics for Different Bench-Scale Runs

Run	PB-1	PB-2	PB-3				
Period	15	7	8	15	19	26	29
Feed, T/D	12,000	12,000	12,000	12,000	12,000	12,000	12,000
Total Liquid Products, B/D	44,304	43,361	40,238	41,255	44,404	40,464	39,977
Barrels of Product/Ton of feed	3.69	3.61	3.35	3.44	3.70	3.37	3.33
Total Plant Cost, $MM	2,710	2,813	2,797	2,735	2,805	2,761	2,782
Total Cost, $/BPD of Product	61,166	64,883	69,517	66,731	63,159	68,238	69,578
Net Annual Cost, $MM	561.5	576.0	569.0	544.9	566.0	544.2	544.5
, $/B	38.58	40.44	43.05	40.21	38.81	40.94	41.46
Equivalent Crude Oil Price, $/B	32.51	34.42	37.14	34.18	32.74	34.94	35.47

Figure 1. Simplified Schematic of HTI's Bench Unit Configured for Run PB-03

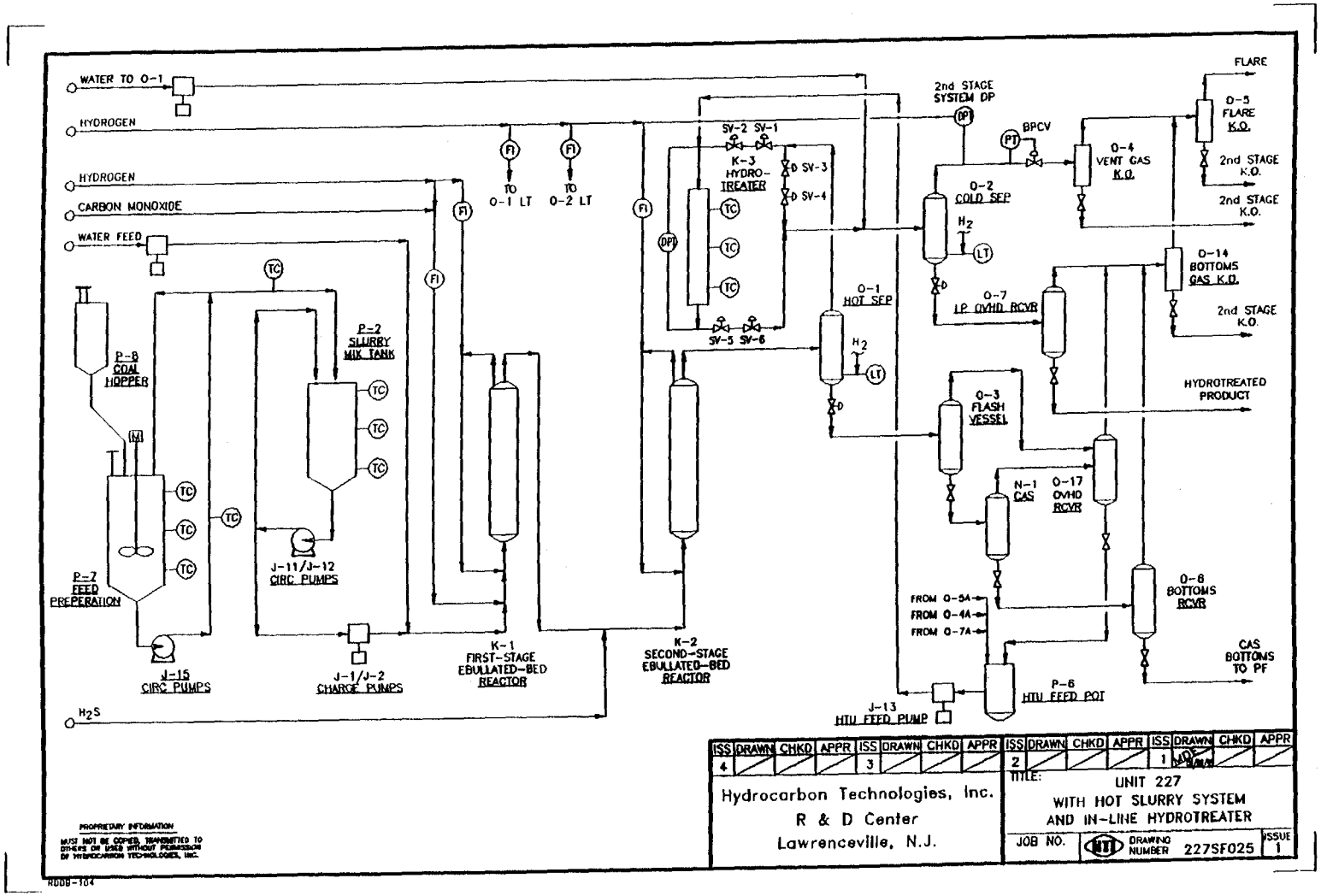


Figure 2. PB-03: Daily Operating Conditions

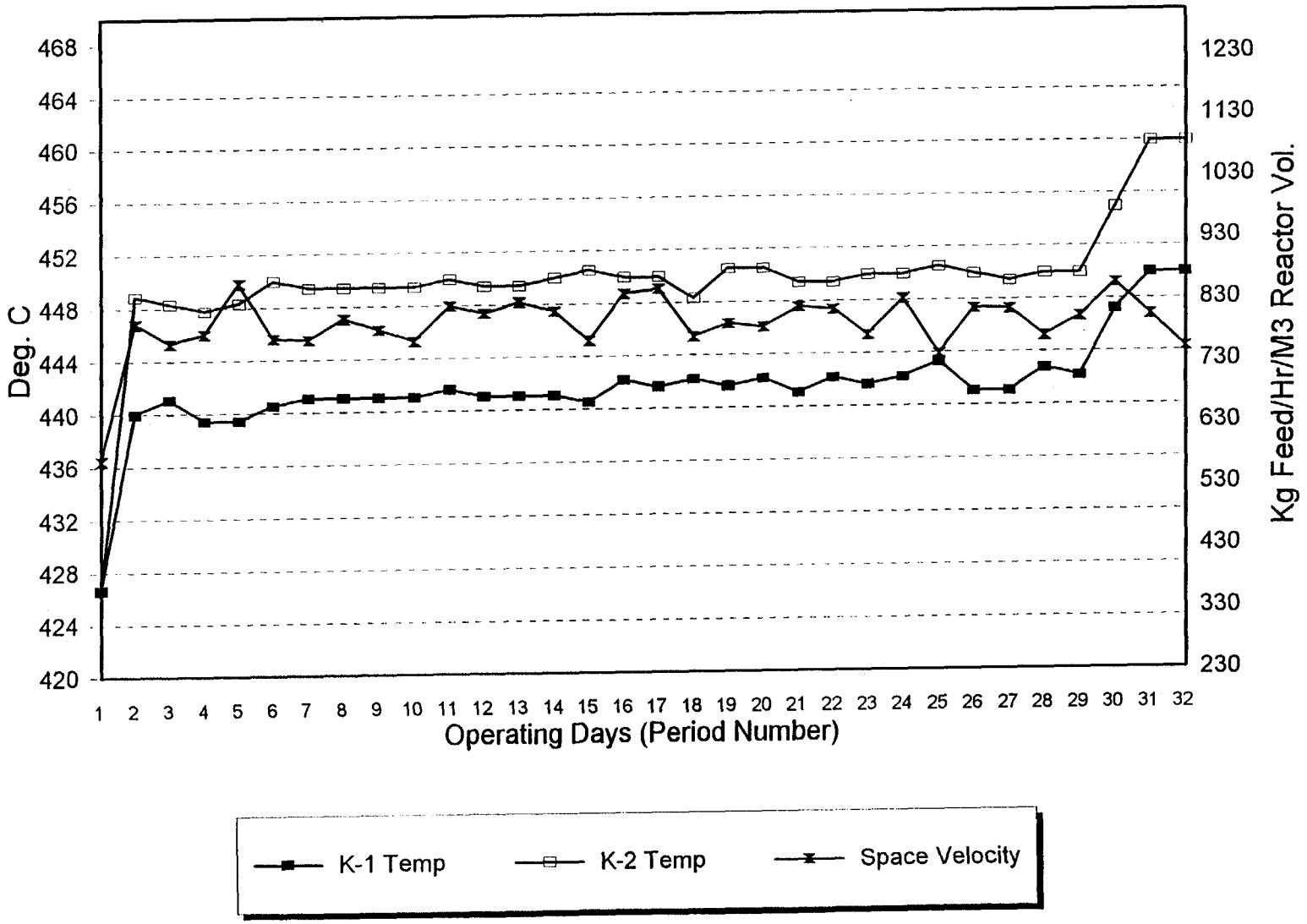


Figure 3. PB-03: Daily Material Recovery Balance

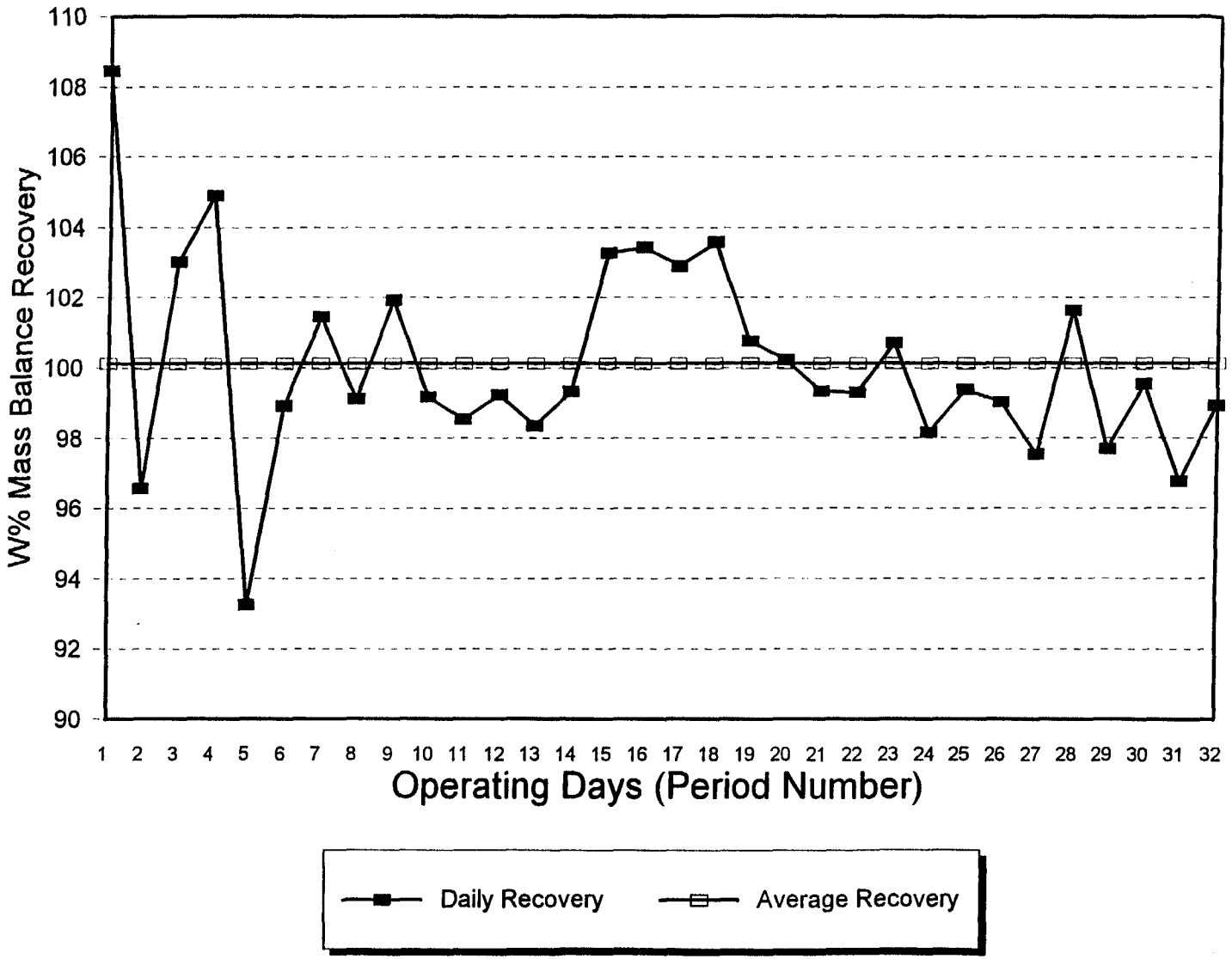


Figure 4. PB-03: Feed and Residuum Conversions

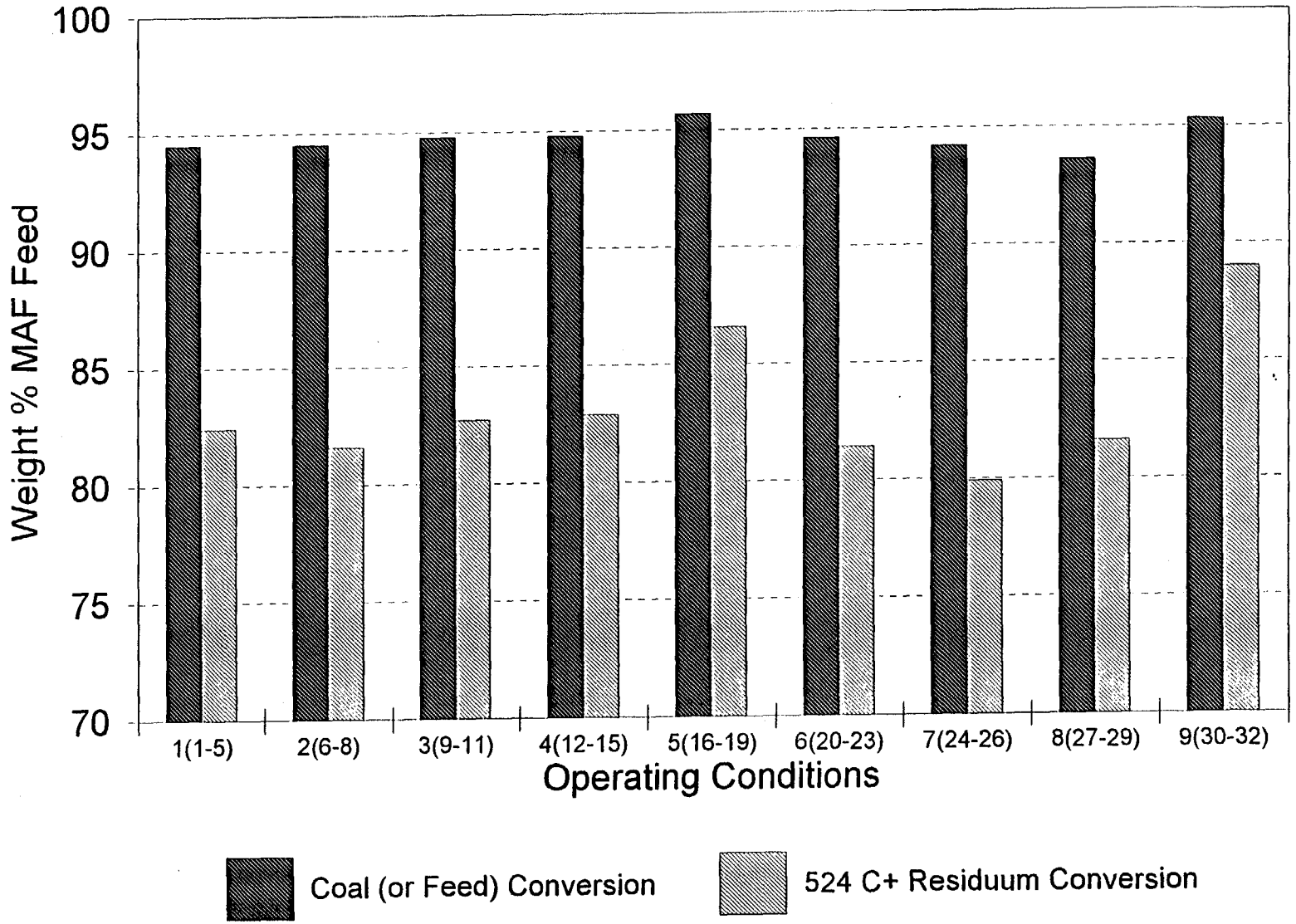


Figure 5. PB-03: C_4-524°C Distillate Yield and 524°C$^+$ Residuum Yield

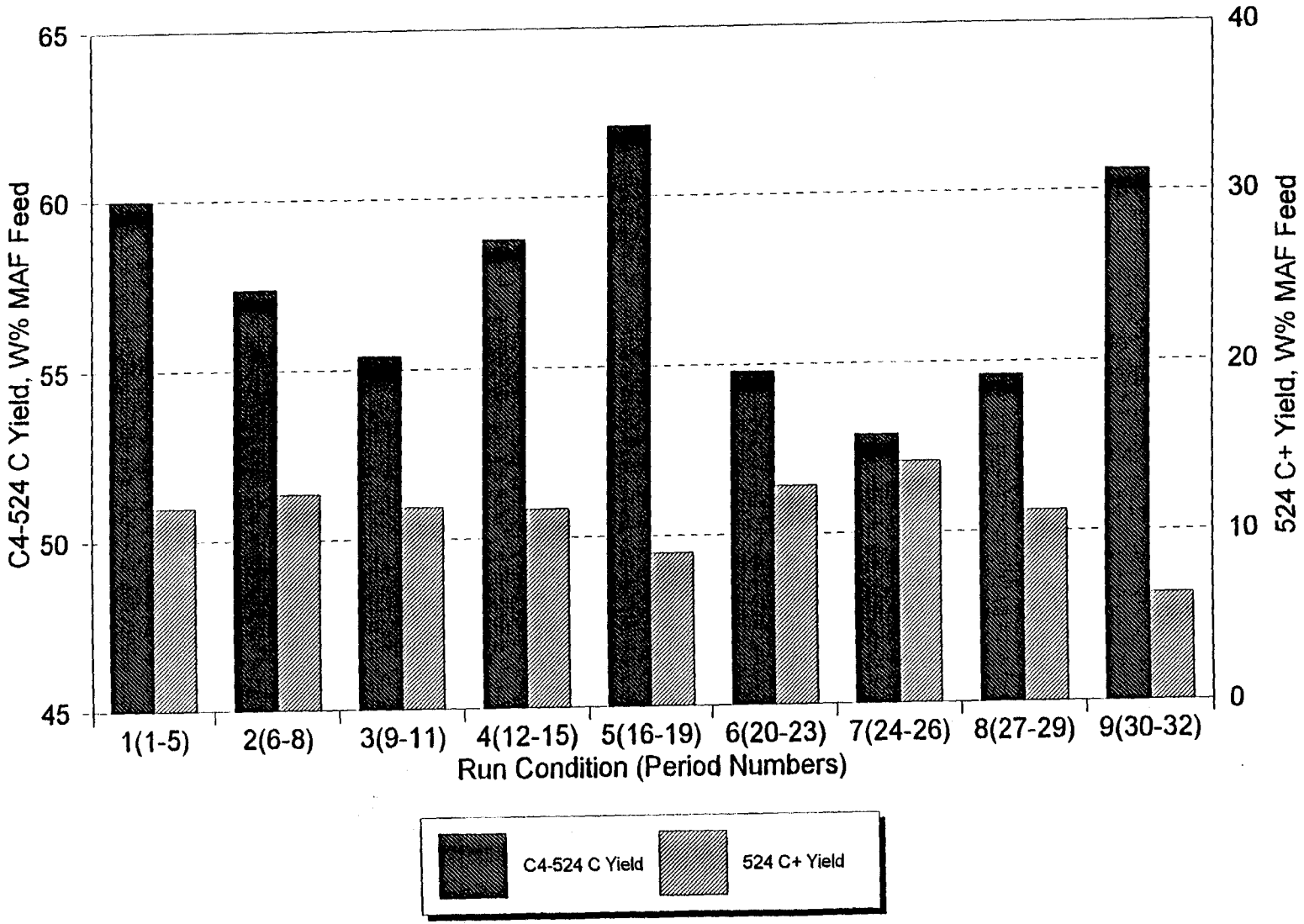


Figure 6. PB-03: Distillate Fraction Yield

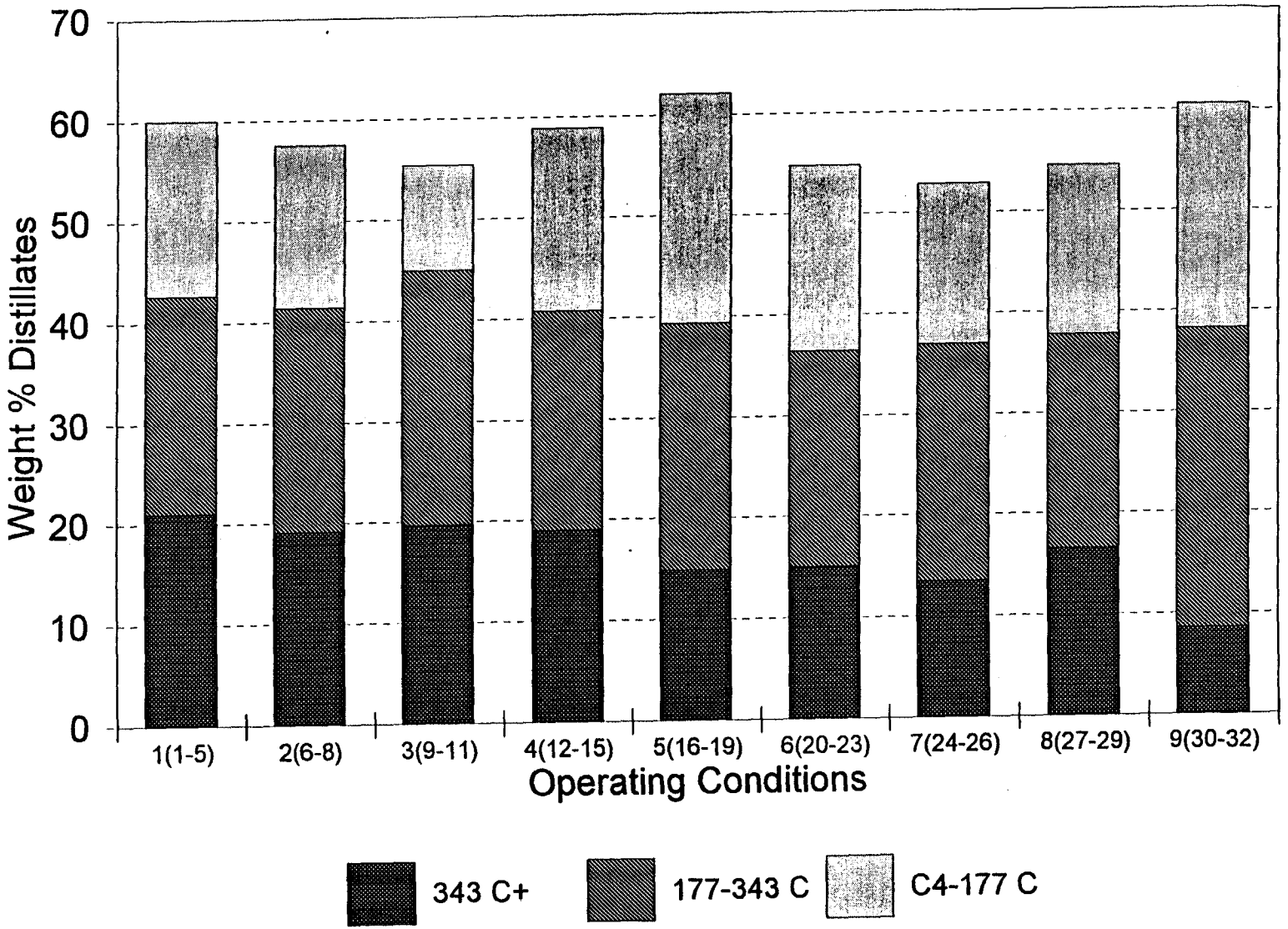


Figure 7. PB-03: Distillate Fraction Selectivity

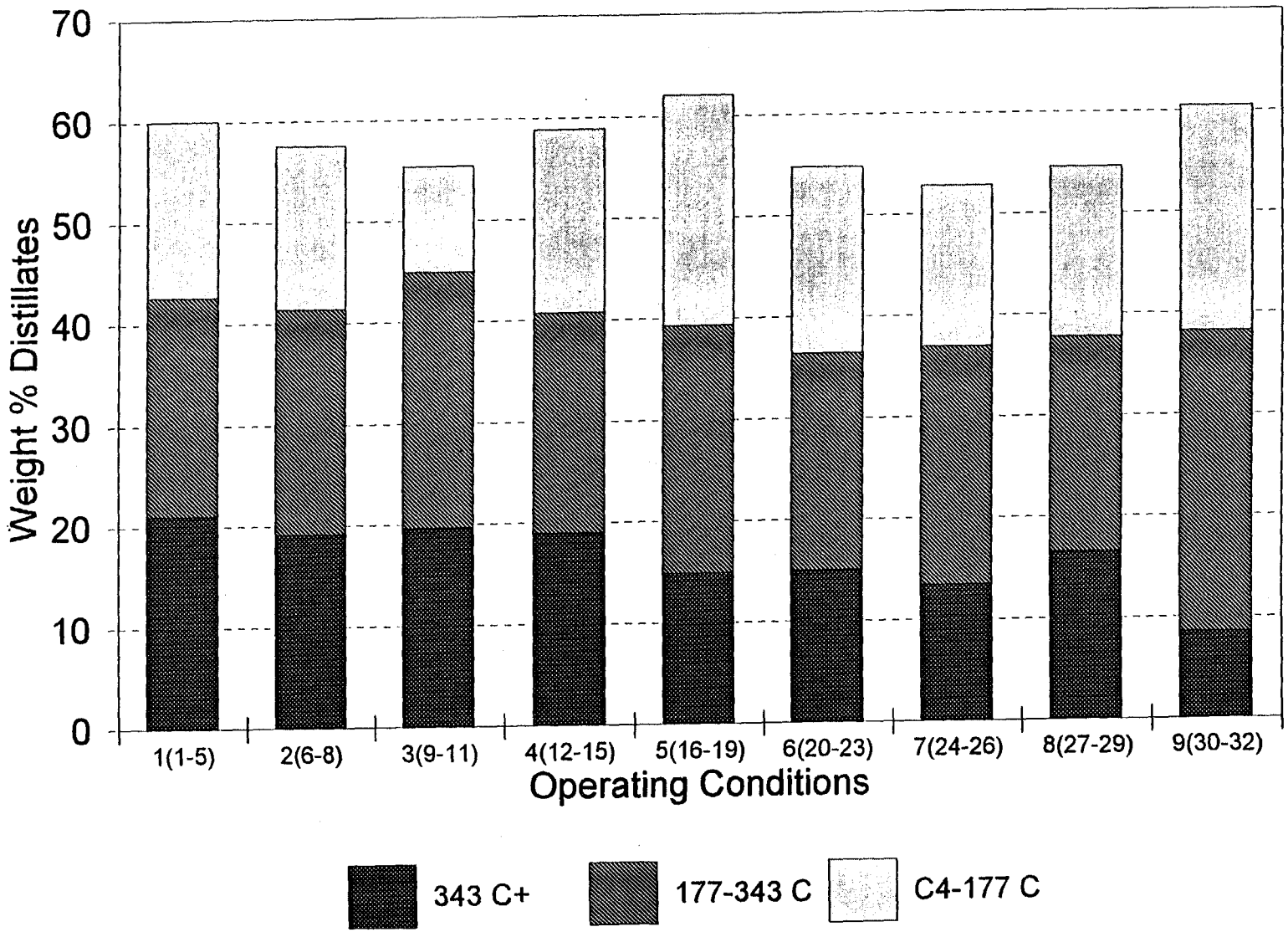


Figure 8. PB-03: Hydrogen Consumption and Light C_1-C_3 Gas Yield

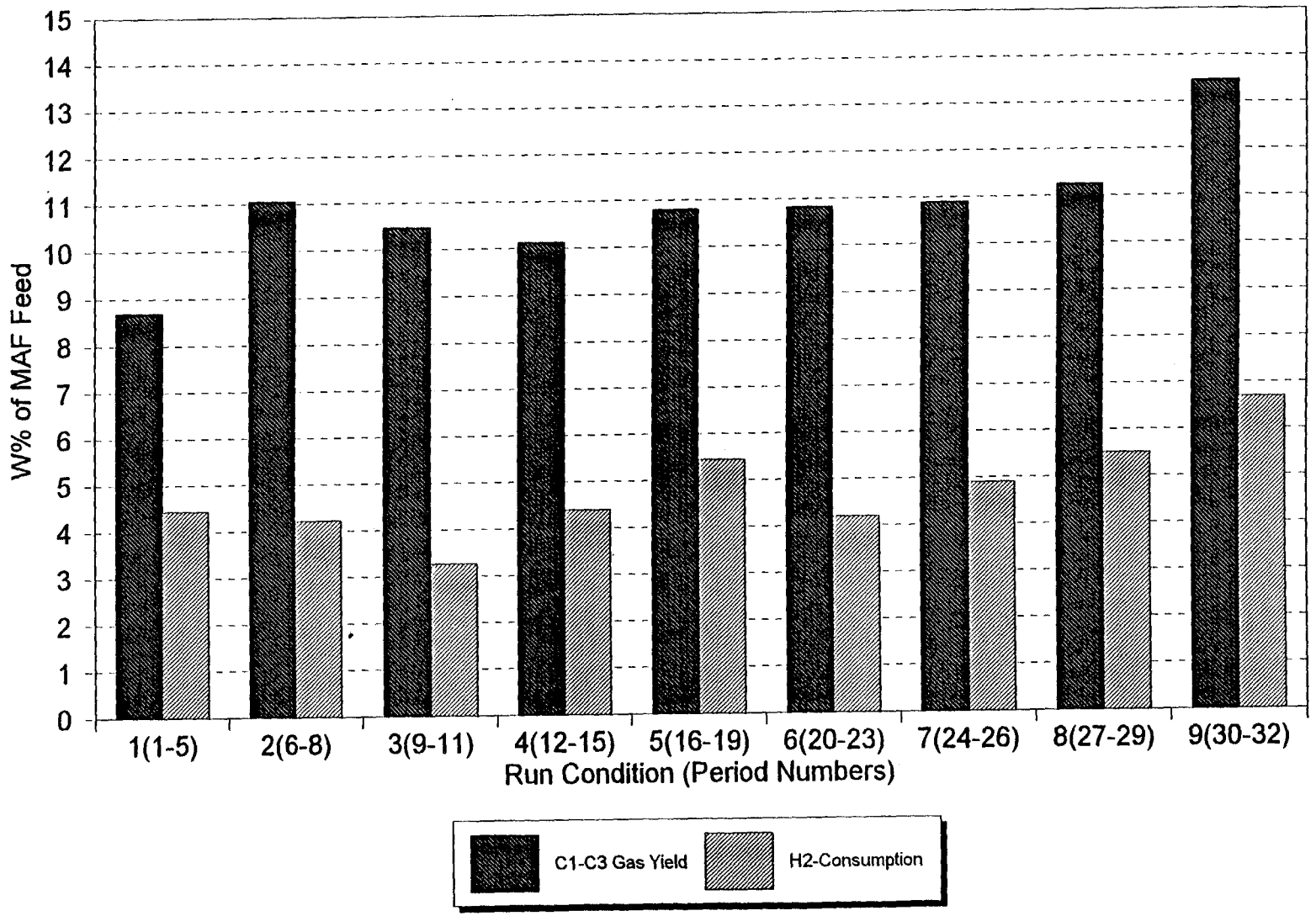


Figure 9. PB-03: Hydrogen Efficiency and C_1-C_3 Gas Selectivity

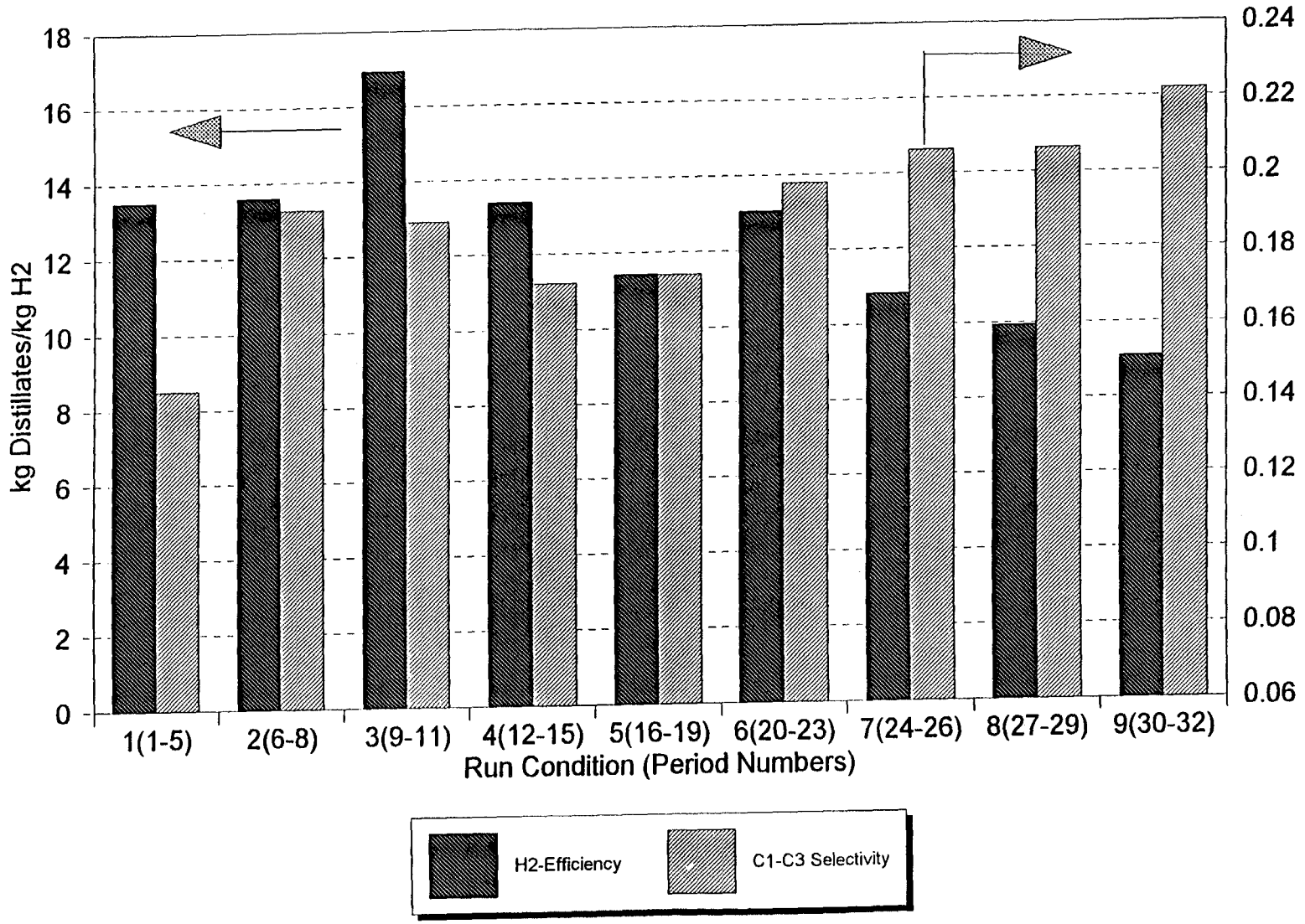


Figure 10. PB-03: Quality of SOH Distillates

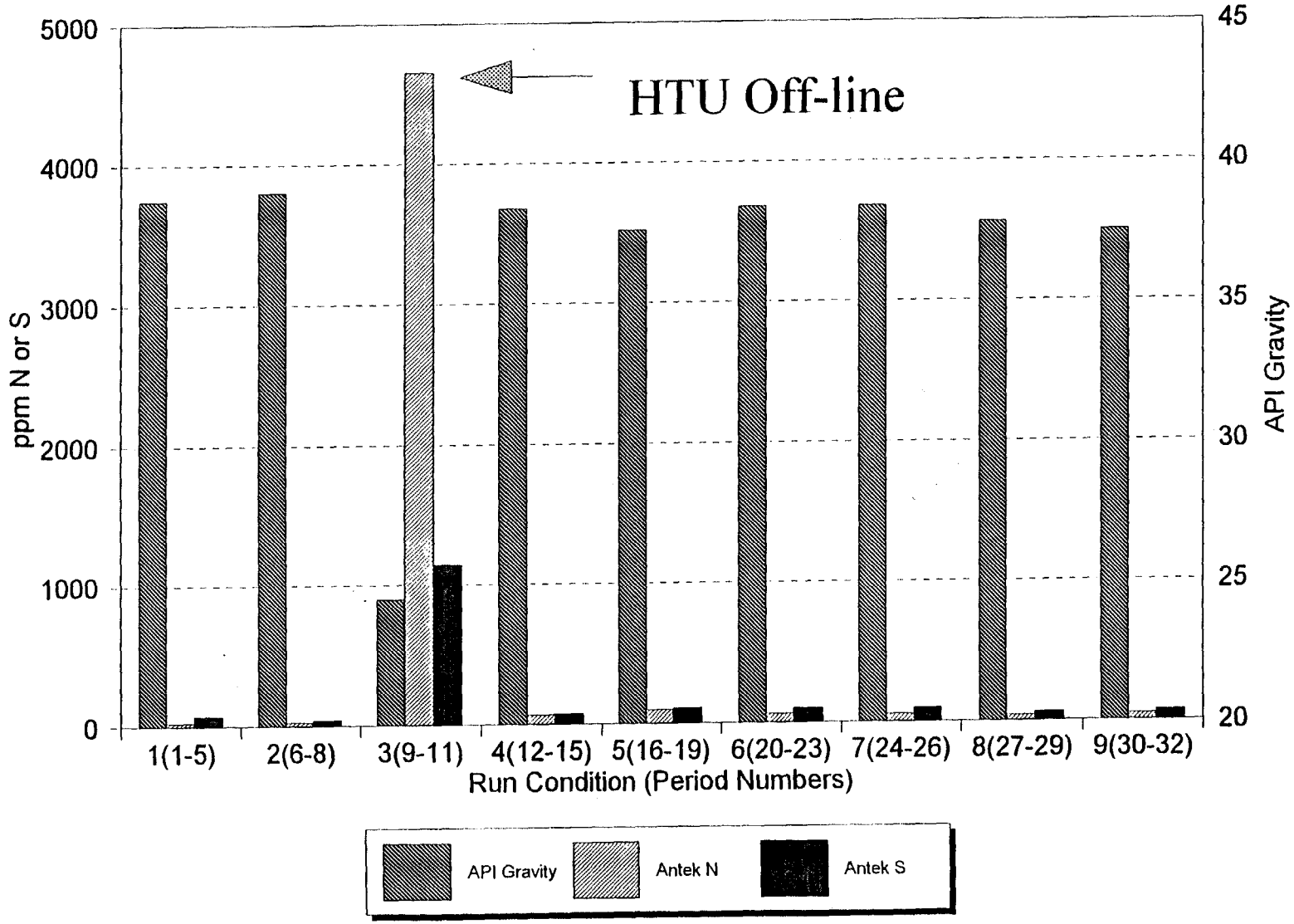


Figure 11. PB-03: Product H/C Ratios

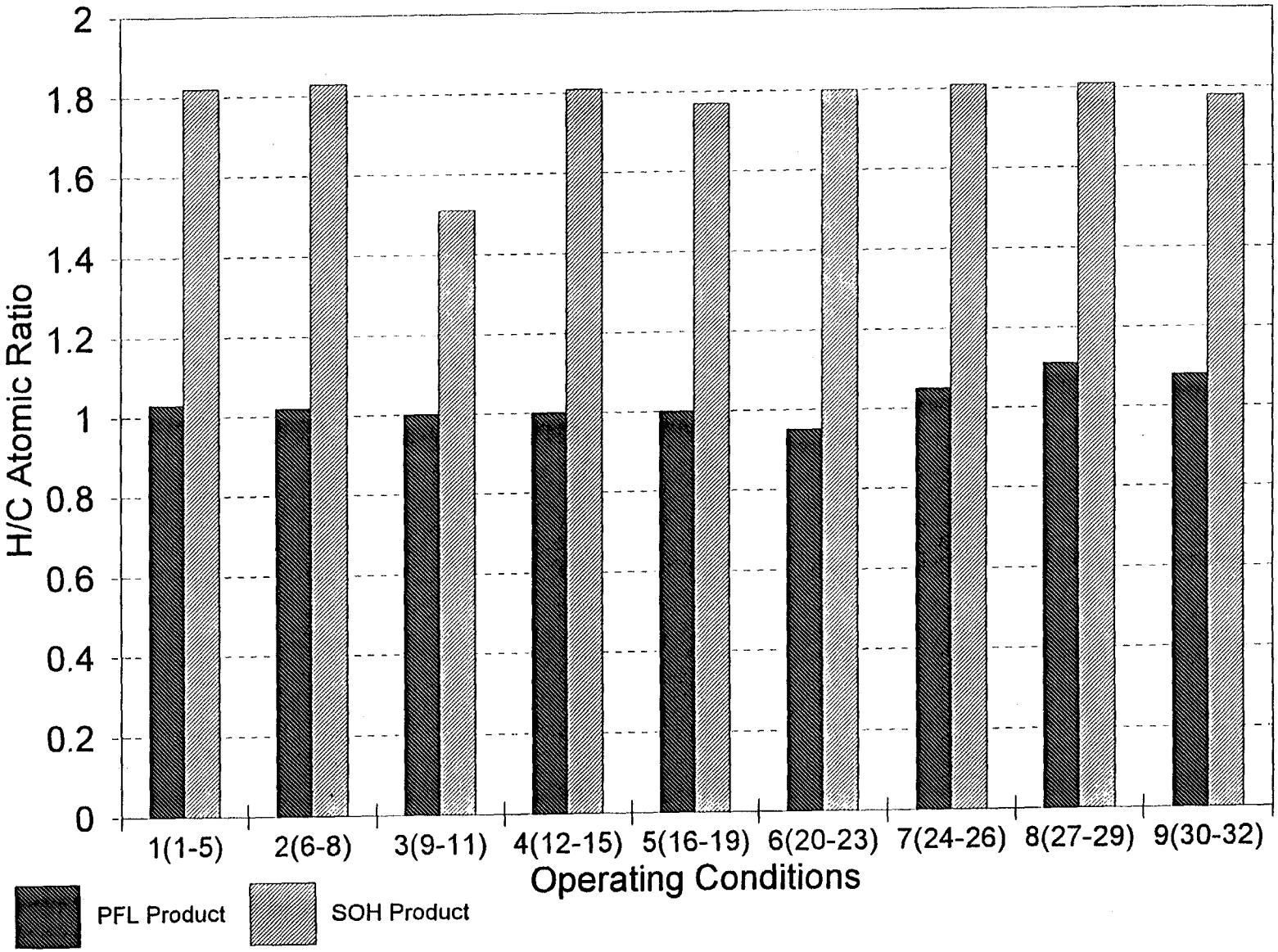


Figure 12. PB-03: Solubility of PFL Product

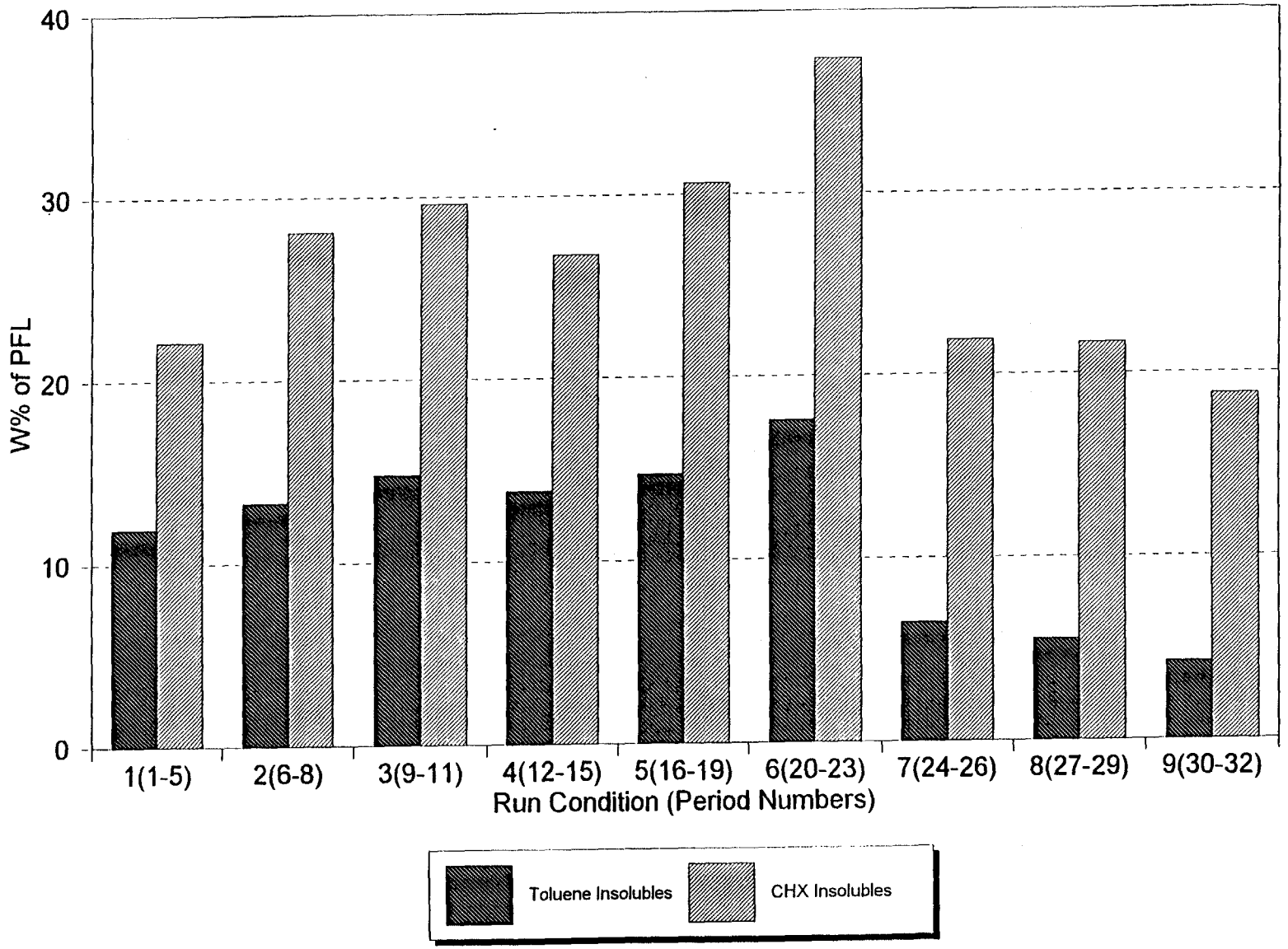


Figure 13. PB-03: Effect of Catalyst Loading on Process Performance

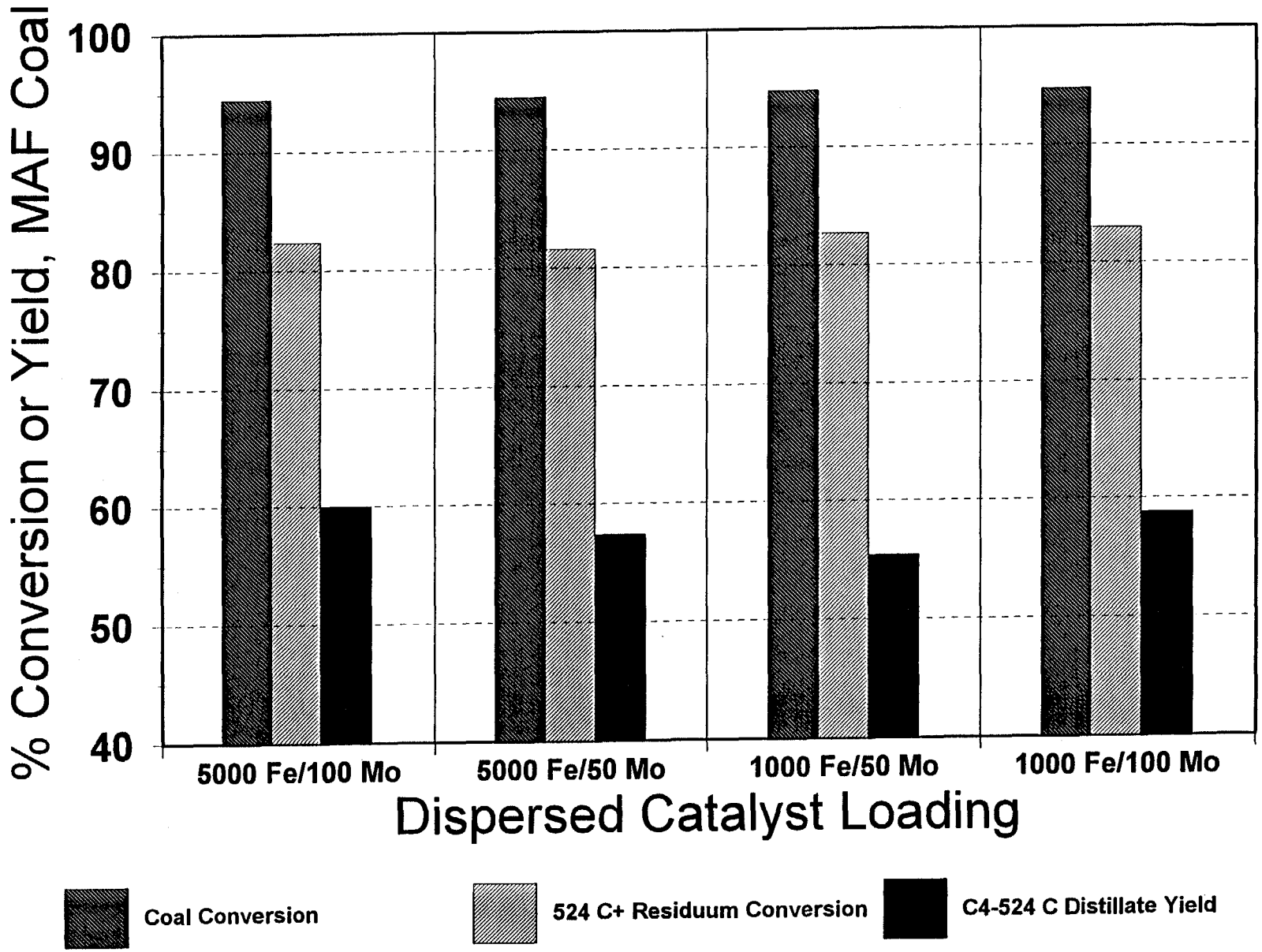


Figure 14. PB-03: Effect of Catalyst Type on Process Performance

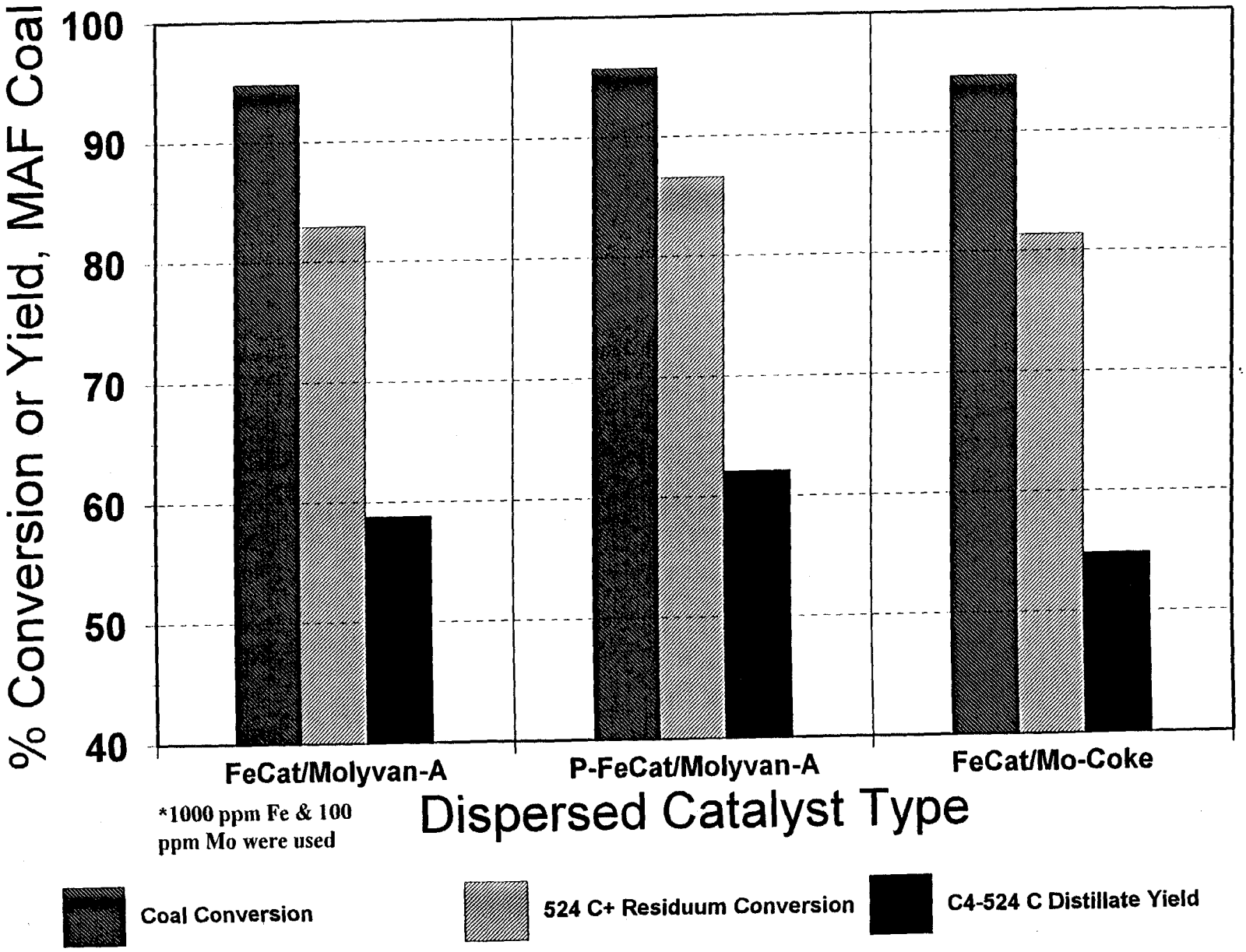


Figure 15. PB-03: Effect of Recycle Solvent Hydrotreatment on Process Performance

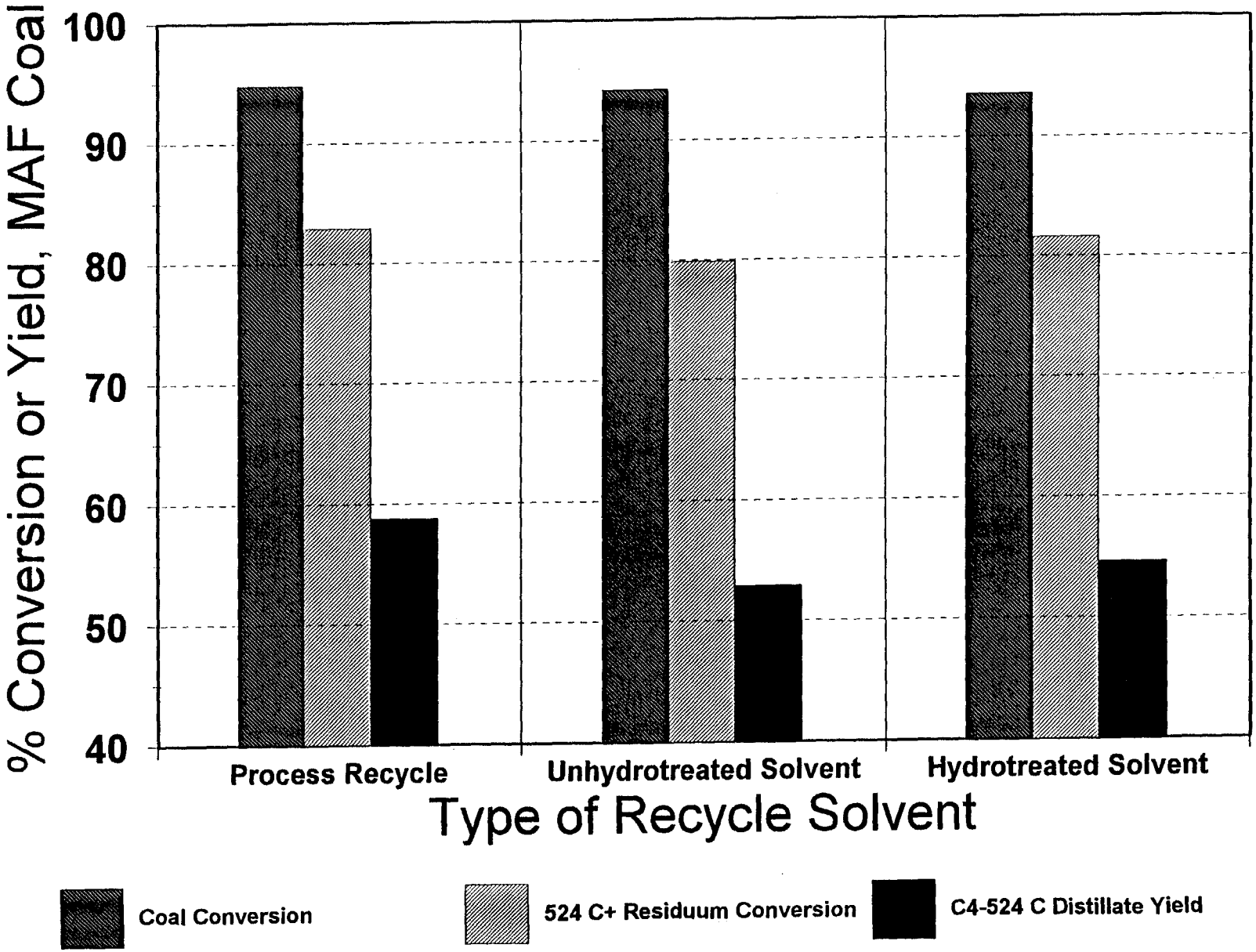


Figure 16. PB-03: Effect of Reactor Gas Velocity on Economics

Reactor gas velocity, PB-3 Period 19

Base:Velocity for supported catalyst

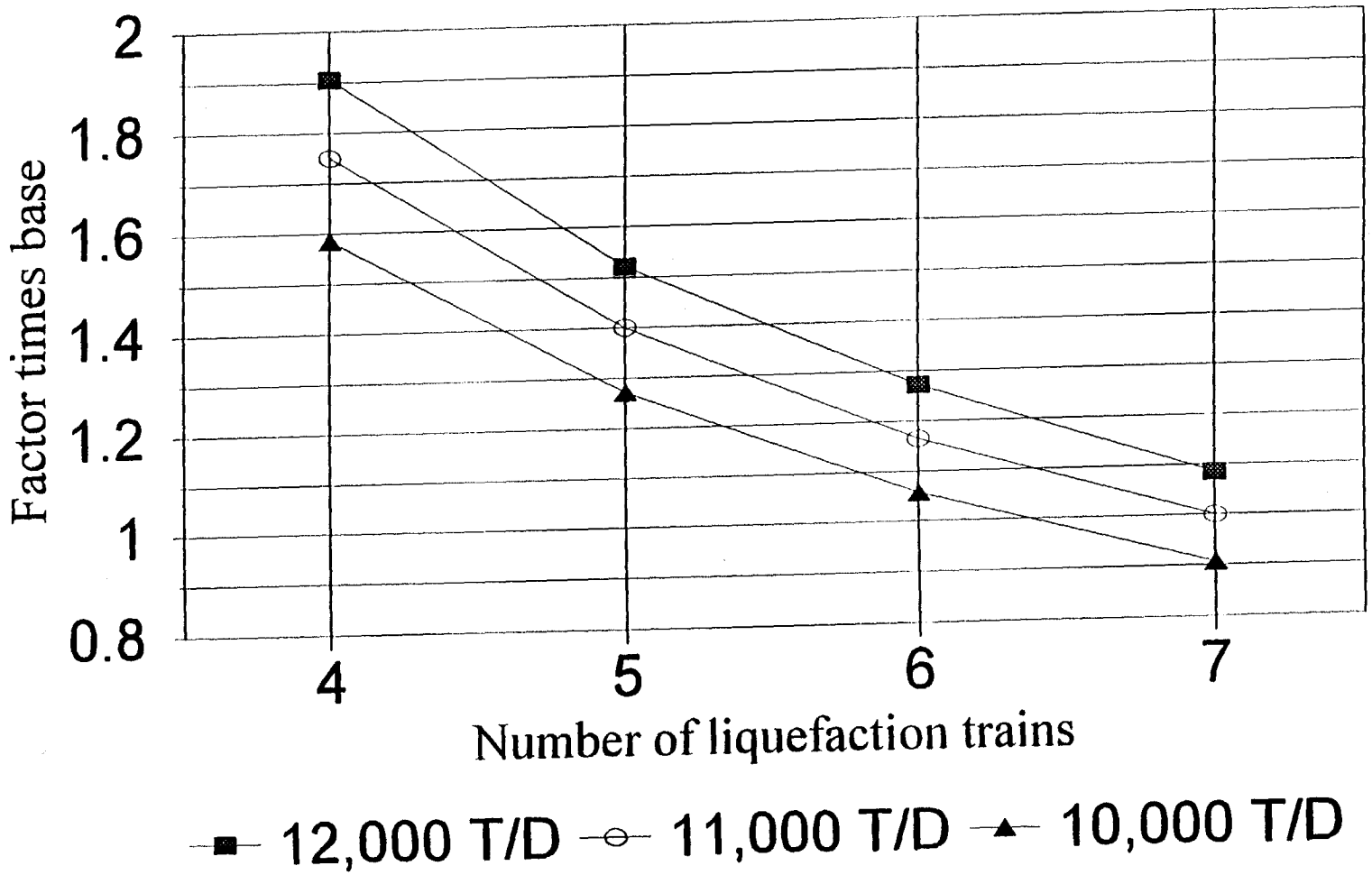


Figure 17. PB-03: Effect of Gas Velocity on Equivalent Crude Price

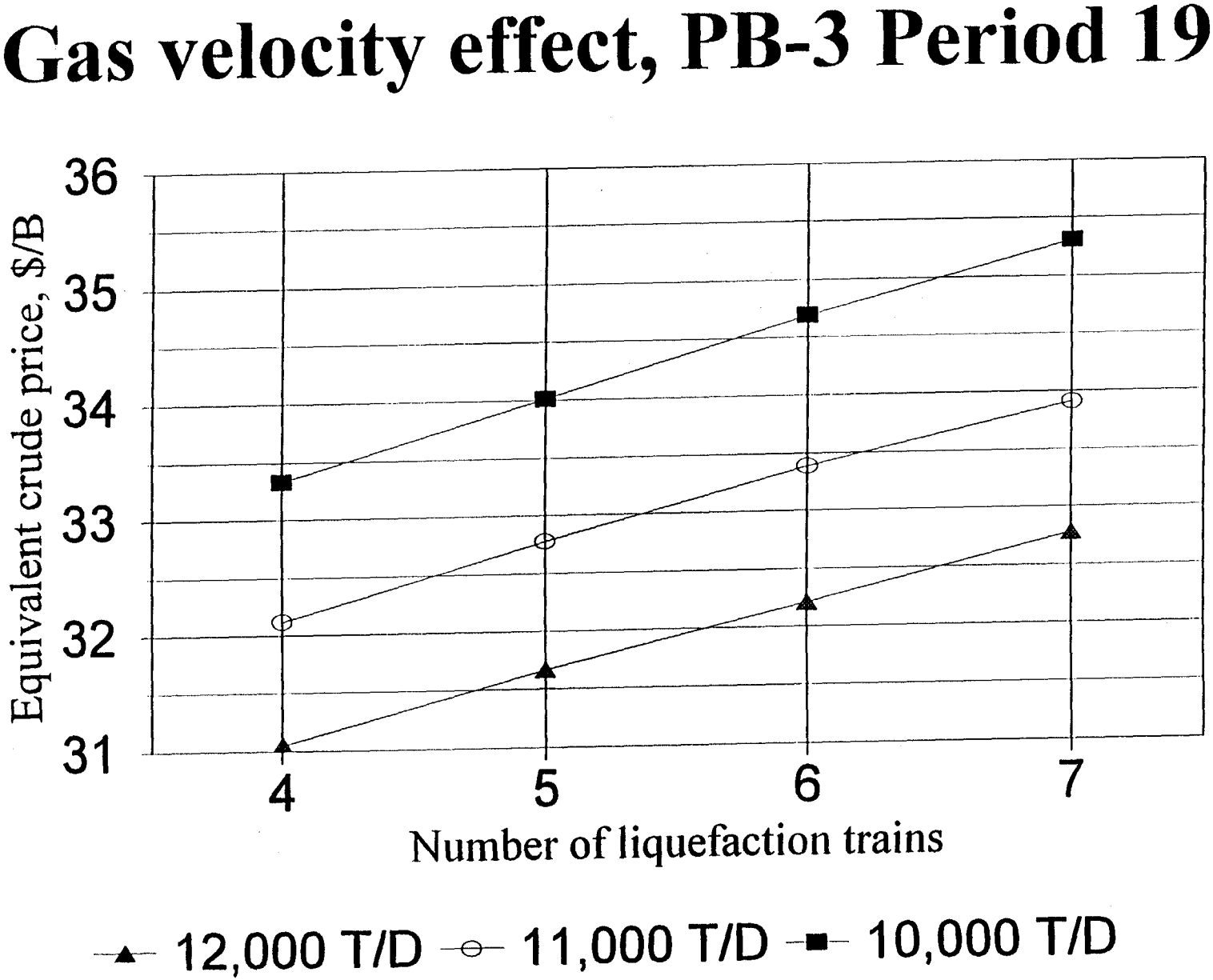
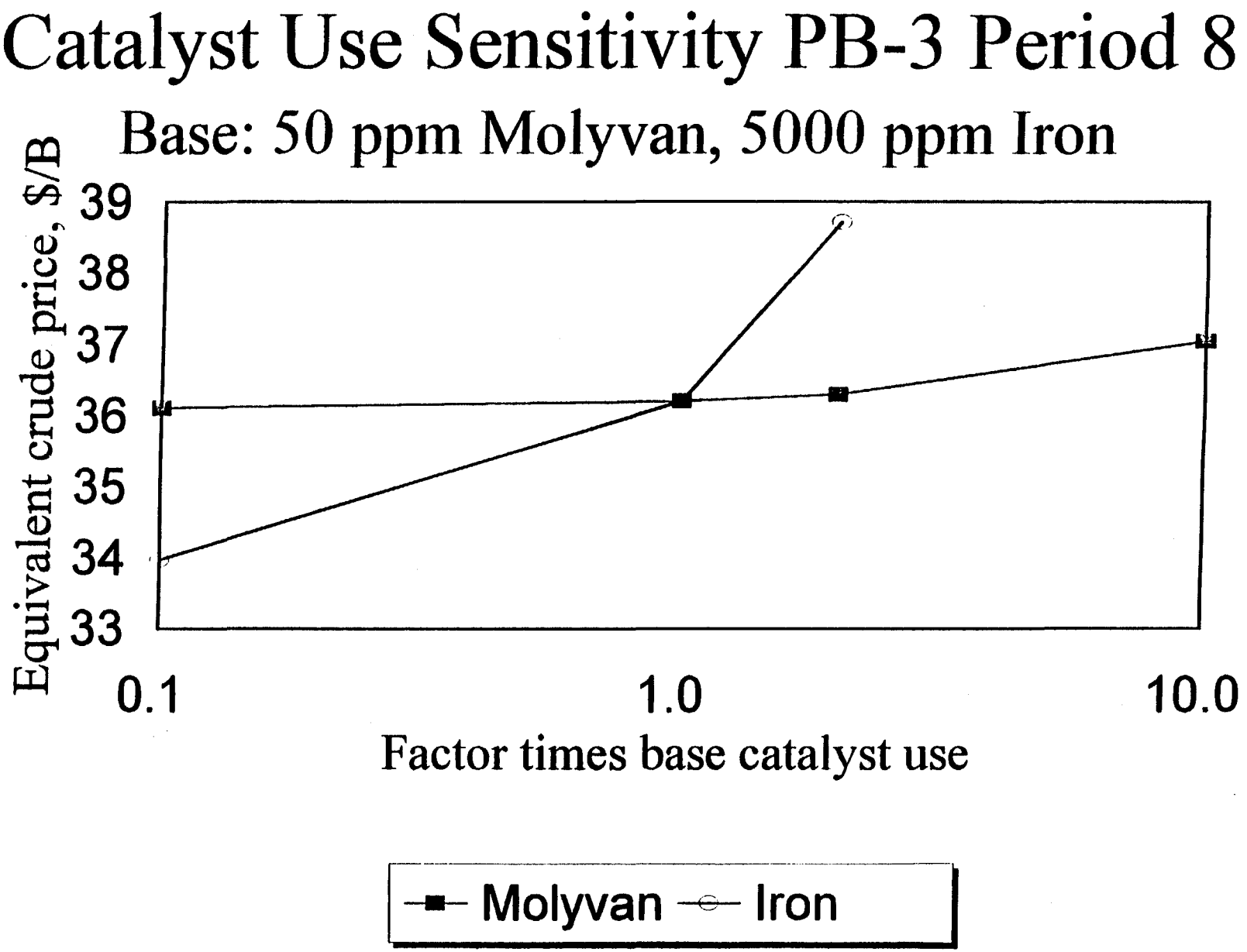


Figure 18. PB-03: Effect of Catalyst Use Sensitivity on Overall Economics



APPENDIX [Daily Material Recovery Balance Data]

The material balance summary and the analysis of product gas streams are listed in the appendix. The material balance summary lists all the input streams to the unit, including recycle, and all the output streams, along with the material recovery balance number (page 1). The temperatures of various fractionators and separators, and pressure filtration data are summarized on page 2. The hourlay feed, recycle, and product stream rates are summarized on page 3, while the yield of product stream, based upon W% moisture-free feed, are listed on page 4. The GC analyses of vent and bottom gases is summarized on page 5. The PFL fed to the buffer includes the PFL material pumped to the ebullating pump hot checks. The normalized yields of individual light gases is also included now in the appendix.

R-96 14:04

RUN 227-93 (POC PB-03) MATERIAL BALANCE

Coal Liquefaction using Dispersed Slurry Fe/Mo Catalysts

COAL: BLACK THUNDER MINE: POC-02 COAL (HRI-6213)

CATALYSTS: HTI'S Fe + MOLYVAN-A (to K-1)

d Number	01T	02T	03T	04T	05T	06T	07T	08T
(Start of Period)	03/03/96	03/04/96	03/05/96	03/06/96	03/07/96	03/08/96	03/09/96	03/10/96
ion, hrs	24.	24.	24.	24.	24.	24.	24.	24.
of Run (End of Period)	24.	48.	72.	96.	120.	144.	168.	192.
S, GRAMS								
oal	31105.0	42921.0	41203.0	41983.0	46312.0	41489.0	41343.0	43104.0
akeup Oil to Charge (L-814/extracted oil)	5309.0	5759.0	0.0	0.0	0.0	0.0	0.0	0.0
akeup Oil to Buffer (L-814/extracted oil)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
fl Recycled to Charge+K-2 Cat Addition	40713.0	37155.0	29145.0	29454.0	46337.0	41511.0	41366.0	43127.0
AS Btms Recycled to Charge	0.0	0.0	12064.0	12551.0	0.0	0.0	0.0	0.0
ilter Cake Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
fl to Stage 1 Buffer	769.0	800.0	762.0	785.0	776.0	725.0	817.0	680.0
fl to Stage 2 Buffer	827.0	700.0	724.0	759.0	833.0	665.0	721.0	870.0
ater to Hot Separators	5196.0	4483.0	4699.0	4671.0	4533.0	4890.0	5106.0	5066.0
otal Sulfur Added	1200.0	1200.0	1200.0	1200.0	1200.0	1200.0	1200.0	1200.0
dditive (Fe+Mo Catalysts)	2775.0	3060.0	2936.0	2993.0	3301.0	2951.0	2941.0	3066.0
2 to 1st Stage	4627.0	4626.9	4627.2	4627.9	4583.7	4628.5	4628.9	4628.4
2 to 2nd Stage	2037.0	2036.7	2036.7	2037.1	2017.3	2028.9	2029.0	2028.9
ydrogen Bleed	697.6	695.2	701.0	701.9	693.8	696.6	696.7	696.6
OTAL GRAMS IN	95255.5	103442.8	100097.9	101762.9	110586.8	100785.0	100848.7	104466.9
TS, GRAMS								
ydrogen Out	5178.9	4736.1	4461.8	4406.1	4393.8	4442.5	4217.1	4280.4
otal Gas Product (N2,H2 Free)	12218.9	8062.6	9851.9	8536.1	8293.5	8040.5	10938.0	8764.2
nit Knockouts	331.0	553.0	530.0	608.0	641.0	591.0	526.0	587.0
eparator Overhead (HTU) Product	14036.0	26522.0	23619.0	23877.0	21664.0	21189.0	22664.0	22022.0
tmospheric Overhead Product (Sample)	0.0	0.0	3.0	116.0	3.0	0.0	0.0	0.0
AS Bottoms	71520.0	59878.0	64551.0	69144.0	67776.0	65362.0	63895.0	66931.0
eed + Interstage Slurry Sample	23.0	154.0	103.0	61.0	376.0	96.0	85.0	972.0
OTAL GRAMS OUT	103307.8	99905.7	103119.7	106748.2	103147.3	99721.1	102325.1	103556.6
Total Material Recovery (Gross)	108.45	96.58	103.02	104.90	93.27	98.94	101.46	99.13

GC TLKL RHS DLT WFK VRP JH

od Number	01T	02T	03T	04T	05T	06T	07T	08T
-SEPARATOR BOTTOMS PRODUCT BREAKDOWN, GRAMS-----								
MOSPHERIC STILL								
CAS Vapor Outlet Temperature, deg-f	82.	87.	91.	88.	81.	78.	80.	85.
CAS Reboiler Temperature, deg-f	109.	111.	115.	114.	109.	107.	107.	110.
CAS Charge	71520.0	59878.0	64554.0	69260.0	67779.0	65362.0	63895.0	66931.0
CAS Overheads to HTU Feed Pot	0.0	0.0	3.0	116.0	3.0	0.0	0.0	0.0
****ASOH AND UNIT KNOCKOUTS ARE BEING FED TO THE HTU*****								
CAS Bottoms	71520.0	59878.0	64551.0	69144.0	67776.0	65362.0	63895.0	66931.0
ESSURE FILTER								
Pressure Filter Charge, gms	71050.0	54744.0	46463.0	59309.0	66872.0	65220.0	63416.0	66097.0
Pressure Filter Cake, gms	5184.0	2576.0	4669.0	5673.0	6947.0	5975.0	5637.0	5398.0
Pressure Filter Liquid, gms	64848.0	49692.0	38790.0	51622.0	56825.0	55836.0	55360.0	57082.0
Pressure Filter Loss, gms	1018.0	2476.0	3004.0	2014.0	3100.0	3409.0	2419.0	3617.0
W% Pfs	7.30	4.71	10.05	9.57	10.39	9.16	8.89	8.17

d Number	.01T	02T	03T	04T	05T	06T	07T	08T
CHARGE, PRODUCT, AND RECYCLE RATES-----								
D RATES, GRAMS/HOUR								
otal Coal Feed	1296.0	1788.4	1716.8	1749.3	1929.7	1728.7	1722.6	1796.0
ry Coal Feed	1166.4	1609.5	1545.1	1574.4	1736.7	1555.8	1550.4	1616.4
otal Makeup Oil Rate	221.2	484.0	0.0	0.0	0.0	0.0	0.0	0.0
ater to Hot Separator	216.5	186.8	195.8	194.6	188.9	203.8	212.8	211.1
2 to 1st Stage	192.8	192.8	192.8	192.8	191.0	192.9	192.9	192.9
2 to 2nd Stage	84.9	84.9	84.9	84.9	84.1	84.5	84.5	84.5
YCLE RATES TO REACTOR, GRAMS/HOUR								
FL Recycled to Slurry + Pretreater Buffer	1696.4	1304.3	1214.4	1227.3	1930.7	1729.6	1723.6	1797.0
AS Bottoms Recycled	0.0	0.0	502.7	523.0	0.0	0.0	0.0	0.0
fl to 1st Stage Buffer	32.0	33.3	31.8	32.7	32.3	30.2	34.0	28.3
fl to 2nd Stage Buffer	34.5	29.2	30.2	31.6	34.7	27.7	30.0	36.3
COLLECTED PRODUCTS (INCLUDING SAMPLES), GRAMS/HOUR								
otal Gas (incl. N2)	766.4	578.5	644.0	603.4	593.7	564.2	674.6	583.7
(N2 free)	724.9	533.3	596.4	539.3	528.6	520.1	631.5	543.9
OH	205.8	525.4	532.0	566.5	483.4	463.4	537.2	498.8
SOH-H2O	379.1	579.7	452.2	428.4	419.3	419.5	407.2	418.8
OH-NET WATER	162.6	392.9	256.4	233.8	230.4	215.8	194.4	207.7
Knockouts	13.8	23.0	22.1	25.3	26.7	24.6	21.9	24.9
ilter Cake	216.0	107.3	194.5	236.4	289.5	249.0	234.9	224.9
ilter Liquid	981.5	806.9	465.1	943.3	499.1	681.0	619.8	667.6
soh + KO	13.8	23.0	22.2	30.2	26.8	24.6	21.9	24.9
otal CAS Bottoms	2980.0	2494.9	2689.6	2881.0	2824.0	2723.4	2662.3	2788.8
eactor 1 Liquid Sample	1.0	6.4	4.3	2.5	15.7	4.0	3.5	40.9
eparator Bottoms to CAS	2980.0	2494.9	2689.8	2885.8	2824.1	2723.4	2662.3	2788.8
otal Asoh	13.8	23.0	22.2	30.2	26.8	24.6	21.9	24.9
AS Bottoms to Pressure Filter	2960.4	2281.0	1936.0	2471.2	2786.3	2717.5	2642.3	2754.0
otal Filter Cake	216.0	107.3	194.5	236.4	289.5	249.0	234.9	224.9
otal Filter Liquid	2744.4	2173.7	1741.4	2234.8	2496.9	2468.5	2407.5	2529.1

d number	01T	02T	03T	04T	05T	06T	07T	08T
GAS RATES:-----								
2 to 1st Stage, scfh	40.0	40.0	40.1	40.1	39.6	40.1	40.1	40.1
2 to 1st Stage Recycle, scfh	40.0	40.0	40.0	40.0	39.7	40.0	40.0	40.0
2 to 2nd Stage, scfh	35.2	35.2	35.2	35.2	34.9	35.1	35.1	35.1
leed H2, scfh	12.1	12.0	12.1	12.1	12.0	12.1	12.1	12.1
ent Gas, scfh (incl. N2)	104.3	92.2	89.4	87.5	87.2	86.9	85.7	84.6
(N2-Free)	103.0	90.9	87.9	85.5	85.2	85.6	84.4	83.4
NET ADJ. PRODUCTS, W% DRY COAL -----								
otal CO + CO2	9.82	4.84	5.23	4.91	4.13	5.11	5.62	5.11
otal C1-C3	20.16	10.32	12.37	11.26	8.27	8.65	15.30	11.20
otal C4-C7	6.21	3.22	3.88	3.67	4.86	3.79	4.52	3.36
SOH TOTAL H2O	32.50	36.01	29.26	27.21	24.14	26.96	26.26	25.91
OH NET WATER	13.94	24.41	16.59	14.85	28.00	13.87	12.54	28.00
OH Distillate Oil	17.64	32.64	34.43	35.98	27.84	29.78	34.65	30.86
soh + KO	1.18	1.43	1.44	1.92	1.55	1.58	1.41	1.51
f1	85.71	62.80	44.72	53.41	30.68	44.12	41.15	43.27
fs	18.64	7.29	14.22	14.33	16.89	16.04	15.26	14.09
AS Bottoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
eactor 1 Liquid Sample	0.08	0.40	0.28	0.16	0.90	0.26	0.23	2.51
OPERATING CONDITIONS-----								
retreater Coil Temp, F								
st Stage Est Reaction Temp, F	800.	824.	826.	823.	823.	825.	826.	826.
nd Stage Est Reaction Temp, F	800.	840.	839.	838.	839.	842.	841.	841.
harge Pot Internal Temp, F	194.	209.	263.	292.	306.	313.	342.	348.
ot Separator Liquid Temp, F	646.	628.	622.	622.	626.	626.	623.	624.
nit Back Pressure, psig	2498.	2497.	2496.	2502.	2500.	2503.	2509.	2507.
retreater Coil DP, psi								
st Stage Reactor DP, psi	5.3	5.6	6.0	5.9	5.6	5.7	6.0	5.8
st Stage Internal Recycle Rate, cc/hr	47640.	47640.	47640.	47640.	47640.	47640.	47640.	47640.
nd Stage Internal Recycle Rate, cc/hr	47640.	47640.	47640.	47640.	47640.	47640.	47640.	47640.
st Stage Dry Coal SV, Lb Feed/Hr/Ft3	36.4	50.2	48.2	49.1	54.2	48.6	48.4	50.5
nd Stage Dry coal SV, Lb Feed/Hr/Ft3	36.4	50.2	48.2	49.1	54.2	48.6	48.4	50.5
wo-Stage Space Velocity, Lb/Hr/Ft3	18.2	25.1	24.1	24.6	27.1	24.3	24.2	25.2
st Stage Slurry Residence Time, min								
nd Stage Slurry Residence Time, min								
oisture in Coal, W%	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
otal Dry Coal Fed to Date, gms	27995.	63824.	100907.	138691.	180372.	217712.	254921.	293715.
2 Consumed--Meter, W% Dry Coal	7.8	6.8	7.8	7.8	7.0	7.8	8.4	7.9

EC-96 09:27

AL: BLACK THUNDER MINE-POC-02 COAL (HRI 6213)

RIOD NUMBER	1	2	3	4	5	6	7	8
S YIELDS (Overheads), W% of mf coal								
	7.61	3.89	4.37	3.92	3.84	3.40	4.21	3.40
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	4.77	2.55	2.93	2.84	2.52	3.05	3.32	2.78
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	7.18	3.38	4.44	3.87	1.37	1.77	7.08	4.41
3	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
4H10	2.96	1.48	1.76	1.61	1.43	1.77	1.96	1.50
4H10	0.00	0.00	0.00	0.00	1.60	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5H12	1.43	0.58	0.65	0.75	0.51	0.61	0.71	0.50
5H12	0.72	0.29	0.35	0.28	0.25	0.28	0.30	0.27
HYL-CYCLOPENTANE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LOHEXANE	0.12	0.06	0.12	0.11	0.15	0.11	0.30	0.05
6H14	0.24	0.12	0.24	0.11	0.10	0.17	0.36	0.16
C7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.71	0.75	0.99	0.94	0.97	0.89	1.05	0.92
	7.85	3.91	4.04	3.75	2.99	3.96	4.21	3.91
	6.98	2.24	4.72	2.48	2.35	3.56	3.57	2.57

RIOD NUMBER	1	2	3	4	5	6	7	8
S YIELDS (Bottoms), W% of mf coal								
	0.09	0.07	0.08	0.08	0.08	0.09	0.08	0.07
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.14	0.12	0.16	0.18	0.15	0.20	0.17	0.17
5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3	0.35	0.30	0.37	0.37	0.30	0.13	0.42	0.35
3	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01
4H10	0.20	0.16	0.22	0.24	0.16	0.29	0.26	0.27
4H10	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5H12	0.11	0.08	0.10	0.11	0.10	0.11	0.11	0.12
5H12	0.06	0.04	0.05	0.05	0.05	0.05	0.05	0.06
HYL-CYCLOPENTANE	0.08	0.06	0.07	0.08	0.09	0.08	0.07	0.08
LOHEXANE	0.14	0.15	0.18	0.17	0.12	0.17	0.17	0.20
6H14	0.09	0.07	0.10	0.10	0.08	0.11	0.10	0.11
C7	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00
	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01
	0.24	0.18	0.19	0.21	0.16	0.25	0.35	0.27
	0.47	0.25	0.37	0.28	0.28	0.41	0.39	0.36

APR-96 14:09

RUN 227-93 (POC PB-03) MATERIAL BALANCE

Coal Liquefaction using Dispersed Slurry Fe/Mo Catalysts

COAL: BLACK THUNDER MINE: POC-02 COAL (HRI-6213)

CATALYSTS: HTI'S Fe + MOLYVAN-A (to K-1)

iod Number	09T	10T	11T	12T	13T	14T	15T	16T
e (Start of Period)	03/11/96	03/12/96	03/13/96	03/14/96	03/15/96	03/16/96	03/17/96	03/18/96
ation, hrs	24.	24.	24.	24.	24.	24.	24.	24.
rs of Run (End of Period)	216.	240.	264.	288.	312.	336.	360.	384.
UTS, GRAMS								
Coal	42235.0	41154.0	44168.0	43454.0	44403.0	43559.0	41005.0	45048.0
Makeup Oil to Charge (L-814/extracted oil)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Makeup Oil to Buffer (L-814/extracted oil)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl Recycled to Charge+K-2 Cat Addition	42259.0	41154.0	44168.0	43454.0	44403.0	43559.0	41005.0	45048.0
CAS Btms Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Filter Cake Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to Stage 1 Buffer	665.0	750.0	848.0	735.0	663.0	932.0	964.0	1287.0
Pfl to Stage 2 Buffer	695.0	946.0	738.0	644.0	802.0	725.0	846.0	1154.0
Water to Hot Separators	4968.0	5064.0	5018.0	5159.0	4936.0	4915.0	5116.0	4855.0
Total Sulfur Added	1200.0	1200.0	1200.0	1200.0	1200.0	1200.0	1200.0	1200.0
Additive (Fe+Mo Catalysts)	606.0	591.0	634.0	631.0	645.0	632.0	596.0	654.0
H2 to 1st Stage	4628.3	4627.7	4627.4	4626.2	4626.7	4626.8	4626.6	4626.6
H2 to 2nd Stage	2028.8	2028.6	2028.7	2028.4	2028.7	2028.8	2028.7	2028.7
Hydrogen Bleed	696.6	696.5	696.5	696.5	696.5	696.5	696.5	696.5
TOTAL GRAMS IN	99981.7	98211.9	104126.6	102628.0	104403.9	102874.1	98083.8	106597.9
UTS, GRAMS								
Hydrogen Out	4370.5	4853.5	4848.1	4434.3	4367.0	4688.1	4496.1	4651.5
Total Gas Product (N2,H2 Free)	9090.7	8497.9	8639.4	9308.1	10985.6	8410.7	8994.0	12762.2
Unit Knockouts	557.0	473.0	552.0	540.0	609.0	532.0	581.0	646.0
Separator Overhead (HTU) Product	20599.0	20818.0	21275.0	21759.0	19895.0	23653.0	21068.0	22665.0
Atmospheric Overhead Product (Sample)	0.0	0.0	0.0	1.0	0.0	0.0	0.0	7.0
CAS Bottoms	67165.0	62609.0	66307.0	65713.0	66733.0	64828.0	65036.0	69447.0
Feed + Interstage Slurry Sample	138.0	157.0	982.0	87.0	93.0	71.0	1128.0	100.0
TOTAL GRAMS OUT	101920.2	97408.4	102603.4	101842.5	102682.6	102182.8	101303.1	110278.7
% Total Material Recovery (Gross)	101.94	99.18	98.54	99.23	98.35	99.33	103.28	103.45

AGC TLKL RHS DLT WFK VRP JH

od Number	09T	10T	11T	12T	13T	14T	15T	16T
SEPARATOR BOTTOMS PRODUCT BREAKDOWN, GRAMS-----								
MOSPHERIC STILL								

TAS Vapor Outlet Temperature, deg-f	87.	90.	90.	94.	87.	84.	90.	90.
TAS Reboiler Temperature, deg-f	111.	113.	112.	116.	112.	110.	112.	113.
TAS Charge	67165.0	62609.0	66307.0	65714.0	66733.0	64828.0	65036.0	69454.0
TAS Overheads to HTU Feed Pot	0.0	0.0	0.0	1.0	0.0	0.0	0.0	7.0
****ASOH AND UNIT KNOCKOUTS ARE BEING FED TO THE HTU*****								
TAS Bottoms	67165.0	62609.0	66307.0	65713.0	66733.0	64828.0	65036.0	69447.0
ESSURE FILTER								
----------								
ressure Filter Charge, gms	66466.0	62144.0	65476.0	65249.0	67253.0	64470.0	64231.0	68903.0
ressure Filter Cake, gms	4636.0	6752.0	5465.0	5196.0	5455.0	5870.0	5670.0	5428.0
ressure Filter Liquid, gms	58290.0	50325.0	58012.0	57950.0	59655.0	57349.0	54644.0	61511.0
ressure Filter Loss, gms	3540.0	5067.0	1999.0	2103.0	2143.0	1251.0	3917.0	1964.0
% Pfs	6.97	10.87	8.35	7.96	8.11	9.11	8.83	7.88

od Number	09T	10T	11T	12T	13T	14T	15T	16T
-CHARGE, PRODUCT, AND RECYCLE RATES-----								
ED RATES, GRAMS/HOUR								
Total Coal Feed	1759.8	1714.8	1840.3	1810.6	1850.1	1815.0	1708.5	1877.0
Dry Coal Feed	1583.8	1543.3	1656.3	1629.5	1665.1	1633.5	1537.7	1689.3
Total Makeup Oil Rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water to Hot Separator	207.0	211.0	209.1	215.0	205.7	204.8	213.2	202.3
H2 to 1st Stage	192.8	192.8	192.8	192.8	192.8	192.8	192.8	192.8
H2 to 2nd Stage	84.5	84.5	84.5	84.5	84.5	84.5	84.5	84.5
CYCLE RATES TO REACTOR, GRAMS/HOUR								
PFL Recycled to Slurry + Pretreater Buffer	1760.8	1714.8	1840.3	1810.6	1850.1	1815.0	1708.5	1877.0
CAS Bottoms Recycled	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to 1st Stage Buffer	27.7	31.3	35.3	30.6	27.6	38.8	40.2	53.6
Pfl to 2nd Stage Buffer	29.0	39.4	30.8	26.8	33.4	30.2	35.3	48.1
T COLLECTED PRODUCTS (INCLUDING SAMPLES), GRAMS/HOUR								
Total Gas (incl. N2)	594.4	594.5	593.8	609.3	683.9	585.3	608.0	768.6
(N2 free)	560.9	556.3	562.0	572.6	639.7	545.8	562.1	725.6
SOH	490.0	475.0	461.8	514.4	427.2	545.5	442.6	492.8
SOH-H2O	368.3	392.4	424.7	392.2	401.8	440.0	435.2	451.6
SOH-NET WATER	161.3	181.4	215.6	177.3	196.1	235.2	222.0	249.3
Knockouts	23.2	19.7	23.0	22.5	25.4	22.2	24.2	26.9
Filter Cake	193.2	281.3	227.7	216.5	227.3	244.6	236.3	226.2
Filter Liquid	758.8	522.6	594.0	634.2	663.8	557.7	656.1	666.1
Asoh + KO	23.2	19.7	23.0	22.5	25.4	22.2	24.2	27.2
Total CAS Bottoms	2798.5	2608.7	2762.8	2738.0	2780.5	2701.2	2709.8	2893.6
Reactor 1 Liquid Sample	5.8	6.5	40.9	3.6	3.9	3.0	47.0	4.2
Separator Bottoms to CAS	2798.5	2608.7	2762.8	2738.1	2780.5	2701.2	2709.8	2893.9
Total Asoh	23.2	19.7	23.0	22.5	25.4	22.2	24.2	27.2
CAS Bottoms to Pressure Filter	2769.4	2589.3	2728.2	2718.7	2802.2	2686.3	2676.3	2871.0
Total Filter Cake	193.2	281.3	227.7	216.5	227.3	244.6	236.3	226.2
Total Filter Liquid	2576.3	2308.0	2500.5	2502.2	2574.9	2441.7	2440.0	2644.8

bd number	09T	10T	11T	12T	13T	14T	15T	16T
GAS RATES:-----								
H2 to 1st Stage, scfh	40.1	40.1	40.1	40.0	40.0	40.0	40.0	40.0
H2 to 1st Stage Recycle, scfh	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
H2 to 2nd Stage, scfh	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1
bleed H2, scfh	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
Vent Gas, scfh (incl. N2)	85.9	94.2	94.1	87.7	88.1	91.4	88.3	94.4
(N2-Free)	84.9	93.0	93.1	86.6	86.8	90.2	86.9	93.1
NET ADJ. PRODUCTS, W% DRY COAL -----								
Total CO + CO2	4.46	5.34	4.50	4.54	8.74	4.87	4.15	6.26
Total C1-C3	13.43	10.11	10.32	11.67	11.60	9.01	10.45	12.55
Total C4-C7	3.03	3.95	3.41	4.03	4.07	3.71	6.27	8.54
SOH TOTAL H2O	23.25	25.42	25.64	24.07	24.13	26.94	28.30	26.73
SOH NET WATER	10.18	11.75	28.00	10.88	11.78	14.40	28.00	14.76
SOH Distillate Oil	30.94	30.78	27.88	31.57	25.66	33.40	28.79	29.17
Asoh + KO	1.47	1.28	1.39	1.38	1.52	1.36	1.57	1.61
ffl	49.62	34.98	37.78	40.01	38.67	34.97	44.66	40.67
ffs	12.32	18.37	13.92	13.38	13.54	15.06	15.56	13.49
TAS Bottoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reactor 1 Liquid Sample	0.36	0.42	2.47	0.22	0.23	0.18	3.06	0.25
OPERATING CONDITIONS-----								
Pretreater Coil Temp, F								
1st Stage Est Reaction Temp, F	826.	826.	827.	826.	826.	826.	825.	828.
2nd Stage Est Reaction Temp, F	841.	841.	842.	841.	841.	842.	843.	842.
Charge Pot Internal Temp, F	358.	358.	354.	361.	363.	360.	334.	343.
Hot Separator Liquid Temp, F	624.	623.	624.	625.	626.	624.	624.	624.
Unit Back Pressure, psig	2501.	2491.	2495.	2497.	2500.	2505.	2506.	2505.
Pretreater Coil DP, psi								
1st Stage Reactor DP, psi	5.7	6.0	5.9	6.2	5.9	6.1	6.0	6.1
1st Stage Internal Recycle Rate, cc/hr	47640.	47640.	47640.	47640.	47640.	47640.	47640.	47640.
2nd Stage Internal Recycle Rate, cc/hr	47640.	47640.	47640.	47640.	47640.	47640.	47640.	47640.
1st Stage Dry Coal SV, Lb Feed/Hr/Ft3	49.4	48.2	51.7	50.9	52.0	51.0	48.0	52.7
2nd Stage Dry coal SV, Lb Feed/Hr/Ft3	49.4	48.2	51.7	50.9	52.0	51.0	48.0	52.7
Two-Stage Space Velocity, Lb/Hr/Ft3	24.7	24.1	25.8	25.4	26.0	25.5	24.0	26.4
1st Stage Slurry Residence Time, min	35.6	36.5	34.0	34.6	33.9	34.4	36.5	33.1
2nd Stage Slurry Residence Time, min	35.3	36.1	33.7	34.3	33.6	34.1	36.1	32.7
Moisture in Coal, W%	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Total Dry Coal Fed to Date, gms	331726.	368765.	408516.	447624.	487587.	526790.	563695.	604238.
H2 Consumed--Meter, W% Dry Coal	7.8	6.7	6.3	7.5	7.5	6.8	7.7	6.7

AL: BLACK THUNDER MINE-POC-02 COAL (HRI 6213)

RIOD NUMBER YIELDS (Overheads), W% of mf coal	9	10	11	12	13	14	15	16
	2.82	3.31	3.14	3.62	3.65	3.36	3.36	4.13
	0.07	0.08	0.06	0.00	0.00	0.00	0.00	0.00
	2.48	2.94	2.54	2.83	3.08	2.88	3.04	3.34
	0.19	0.24	0.20	0.00	0.00	0.00	0.00	0.00
	7.30	2.99	3.79	4.51	4.22	2.30	3.20	3.98
	0.11	0.16	0.15	0.00	0.00	0.00	0.26	0.48
H10	1.26	1.62	1.39	1.57	1.61	1.63	1.04	1.25
H10	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.34
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H12	0.46	0.72	0.48	0.59	0.67	0.66	1.63	2.26
H12	0.23	0.26	0.24	0.27	0.31	0.28	0.38	0.94
YL-CYCLOPENTANE	0.00	0.06	0.00	0.00	0.00	0.00	0.50	0.44
OHEXANE	0.11	0.06	0.11	0.48	0.36	0.05	0.62	0.61
H14	0.17	0.31	0.29	0.27	0.21	0.22	0.34	0.34
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56
	1.32	1.50	1.38	0.91	0.98	0.88	1.04	1.15
	2.95	3.68	2.93	3.34	7.47	3.73	2.93	4.89
	2.67	3.21	3.15	3.18	2.64	3.43	2.99	3.47

IOD NUMBER YIELDS (Bottoms), W% of mf coal	9	10	11	12	13	14	15	16
	0.05	0.06	0.07	0.07	0.08	0.07	0.11	0.12
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.12	0.12	0.14	0.18	0.19	0.19	0.22	0.29
	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
	0.38	0.34	0.37	0.45	0.38	0.20	0.50	0.68
	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
H10	0.18	0.18	0.21	0.25	0.28	0.28	0.27	0.35
H10	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.08
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H12	0.08	0.08	0.09	0.10	0.12	0.11	0.16	0.18
H12	0.04	0.04	0.04	0.05	0.06	0.05	0.07	0.08
YL-CYCLOPENTANE	0.07	0.07	0.07	0.07	0.08	0.07	0.09	0.09
OHEXANE	0.21	0.20	0.19	0.24	0.20	0.22	0.14	0.14
H14	0.08	0.08	0.09	0.10	0.11	0.09	0.09	0.10
7	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.10
	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.02
	0.17	0.15	0.18	0.27	0.28	0.26	0.15	0.19
	0.33	0.34	0.36	0.38	0.44	0.44	0.52	0.66

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RUN 227-93 (POC PB-03) MATERIAL BALANCE

Coal Liquefaction using Dispersed Slurry Fe/Mo Catalysts

COAL: BLACK THUNDER MINE: POC-02 COAL (HRI-6213)

CATALYSTS: HTI'S Fe + MOLYVAN-A (to K-1)

od Number	17T	18T	19T	20T	21T	22T	23T
(Start of Period)	03/19/96	03/20/96	03/21/96	03/22/96	03/23/96	03/24/96	03/25/96
tion, hrs	24.	24.	24.	24.	24.	24.	24.
s of Run (End of Period)	408.	432.	456.	480.	504.	528.	552.
TS, GRAMS							
Coal	45447.0	41239.0	42341.0	42022.0	43736.0	43486.0	41267.0
Makeup Oil to Charge (L-814/extracted oil)	0.0	0.0	0.0	500.0	0.0	0.0	2764.0
Makeup Oil to Buffer (L-814/extracted oil)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl Recycled to Charge+K-2 Cat Addition	45447.0	41239.0	42341.0	42022.0	43736.0	43486.0	41267.0
CAS Btms Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Filter Cake Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to Stage 1 Buffer	814.0	680.0	741.0	776.0	744.0	711.0	910.0
Pfl to Stage 2 Buffer	757.0	595.0	688.0	713.0	743.0	914.0	762.0
Water to Hot Separators	4843.0	4750.0	4907.0	5243.0	5249.0	5089.0	5066.0
Total Sulfur Added	1200.0	1200.0	1200.0	1200.0	1200.0	1200.0	1200.0
Additive (Fe+Mo Catalysts)	656.0	599.0	616.0	624.0	649.0	645.0	637.0
H2 to 1st Stage	4626.7	4626.9	4627.4	4627.8	4627.4	4626.5	4627.2
H2 to 2nd Stage	2028.8	2028.8	2028.8	2028.8	2028.8	2028.7	2028.8
Hydrogen Bleed	696.5	696.5	696.6	696.5	696.5	696.5	696.5
TOTAL GRAMS IN	106516.0	97654.2	100186.8	100453.1	103409.7	102882.7	101225.4
UTS, GRAMS							
Hydrogen Out	4405.3	4537.1	4575.6	4529.3	4532.3	4459.8	4473.3
Total Gas Product (N2,H2 Free)	11324.0	9994.8	10185.7	10224.2	9156.6	9690.7	9713.4
Unit Knockouts	649.0	572.0	521.0	563.0	584.0	485.0	473.0
Separator Overhead (HTU) Product	21990.0	21414.0	23184.0	22384.0	22242.0	22838.0	22506.0
Atmospheric Overhead Product (Sample)	0.0	0.0	0.0	0.0	0.0	0.0	1.0
CAS Bottoms	71032.0	64459.0	61727.0	62923.0	66124.0	64589.0	63769.0
Feed + Interstage Slurry Sample	213.0	179.0	767.0	65.0	76.0	102.0	1019.0
TOTAL GRAMS OUT	109613.3	101155.8	100960.4	100688.5	102714.9	102164.5	101954.7
Total Material Recovery (Gross)	102.91	103.59	100.77	100.23	99.33	99.30	100.72

AGC TLKL RHS DLT WFK VRP JH

d Number	17T	18T	19T	20T	21T	22T	23T
EPARATOR BOTTOMS PRODUCT BREAKDOWN, GRAMS-----							
OSPHERIC STILL							

AS Vapor Outlet Temperature, deg-f	87.	87.	88.	86.	86.	91.	90.
AS Reboiler Temperature, deg-f	113.	113.	112.	111.	112.	115.	114.
AS Charge	71032.0	64459.0	61727.0	62923.0	66124.0	64589.0	63770.0
AS Overheads to HTU Feed Pot	0.0	0.0	0.0	0.0	0.0	0.0	1.0
****ASOH AND UNIT KNOCKOUTS ARE BEING FED TO THE HTU*****							
AS Bottoms	71032.0	64459.0	61727.0	62923.0	66124.0	64589.0	63769.0
SURE FILTER							
----------							
essure Filter Charge, gms	69654.0	64412.0	60678.0	62797.0	65739.0	64184.0	63046.0
essure Filter Cake, gms	5429.0	5740.0	5744.0	5381.0	5595.0	5544.0	5090.0
essure Filter Liquid, gms	62043.0	56294.0	52893.0	55581.0	58355.0	56714.0	55980.0
essure Filter Loss, gms	2182.0	2378.0	2041.0	1835.0	1789.0	1926.0	1976.0
Pfs	7.79	8.91	9.47	8.57	8.51	8.64	8.07

od Number	17T	18T	19T	20T	21T	22T	23T
-CHARGE, PRODUCT, AND RECYCLE RATES-----							
ED RATES, GRAMS/HOUR							
Total Coal Feed	1893.6	1718.3	1764.2	1750.9	1822.3	1811.9	1719.5
Dry Coal Feed	1704.3	1546.5	1587.8	1575.8	1640.1	1630.7	1547.5
Total Makeup Oil Rate	0.0	0.0	0.0	20.8	0.0	0.0	115.2
Water to Hot Separator	201.8	197.9	204.5	218.5	218.7	212.0	211.1
H2 to 1st Stage	192.8	192.8	192.8	192.8	192.8	192.8	192.8
H2 to 2nd Stage	84.5	84.5	84.5	84.5	84.5	84.5	84.5
CYCLE RATES TO REACTOR, GRAMS/HOUR							
PFL Recycled to Slurry + Pretreater Buffer	1893.6	1718.3	1764.2	1750.9	1822.3	1811.9	1719.5
CAS Bottoms Recycled	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to 1st Stage Buffer	33.9	28.3	30.9	32.3	31.0	29.6	37.9
Pfl to 2nd Stage Buffer	31.5	24.8	28.7	29.7	31.0	38.1	31.8
T COLLECTED PRODUCTS (INCLUDING SAMPLES), GRAMS/HOUR							
Total Gas (incl. N2)	701.3	651.2	665.4	666.2	620.0	629.0	642.9
(N2 free)	655.4	605.5	615.1	614.7	570.4	589.6	591.1
SOH	469.1	450.8	552.4	514.3	459.0	483.5	480.2
SOH-H2O	447.1	441.5	413.6	418.4	467.7	468.1	457.5
SOH-NET WATER	245.3	243.5	209.2	199.9	249.0	256.0	246.5
Knockouts	27.0	23.8	21.7	23.5	24.3	20.2	19.7
Filter Cake	226.2	239.2	239.3	224.2	233.1	231.0	212.1
Filter Liquid	717.0	673.3	465.2	579.4	621.7	563.7	625.7
Asoh + KO	27.0	23.8	21.7	23.5	24.3	20.2	19.8
Total CAS Bottoms	2959.7	2685.8	2572.0	2621.8	2755.2	2691.2	2657.0
Reactor 1 Liquid Sample	8.9	7.5	32.0	2.7	3.2	4.3	42.5
Separator Bottoms to CAS	2959.7	2685.8	2572.0	2621.8	2755.2	2691.2	2657.1
Total Asoh	27.0	23.8	21.7	23.5	24.3	20.2	19.8
CAS Bottoms to Pressure Filter	2902.3	2683.8	2528.3	2616.5	2739.1	2674.3	2626.9
Total Filter Cake	226.2	239.2	239.3	224.2	233.1	231.0	212.1
Total Filter Liquid	2676.0	2444.7	2288.9	2392.3	2506.0	2443.3	2414.8

od number	17T	18T	19T	20T	21T	22T	23T
-GAS RATES:-----							
H2 to 1st Stage, scfh	40.0	40.0	40.0	40.1	40.0	40.0	40.0
H2 to 1st Stage Recycle, scfh	40.0	40.0	40.0	40.0	40.0	40.0	40.0
H2 to 2nd Stage, scfh	35.1	35.1	35.1	35.1	35.1	35.1	35.1
Bleed H2, scfh	12.1	12.1	12.1	12.1	12.1	12.0	12.1
Vent Gas, scfh (incl. N2)	88.6	89.5	90.7	90.3	89.2	88.3	88.8
(N2-Free)	87.2	88.2	89.2	88.7	87.7	87.1	87.2
-NET ADJ. PRODUCTS, W% DRY COAL -----							
Total CO + CO2	4.44	4.24	3.94	5.46	4.03	4.52	4.82
Total C1-C3	10.80	10.50	10.90	11.20	9.94	10.78	11.18
Total C4-C7	8.92	8.70	8.30	6.56	6.02	6.16	6.78
SOH TOTAL H2O	26.24	28.55	26.05	26.55	28.52	28.70	29.57
SOH NET WATER	14.40	15.75	28.00	12.69	15.18	28.00	15.93
SOH Distillate Oil	27.53	29.15	34.79	32.64	27.99	29.65	31.03
Asoh + KO	1.59	1.54	1.37	1.49	1.48	1.24	1.28
Pfl	45.17	43.65	31.79	37.07	38.80	35.51	42.22
Pfs	13.54	15.48	15.33	14.26	14.30	14.25	13.86
CAS Bottoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reactor 1 Liquid Sample	0.52	0.48	2.01	0.17	0.19	0.26	2.74
-OPERATING CONDITIONS-----							
Pretreater Coil Temp, F							
1st Stage Est Reaction Temp, F	827.	828.	827.	828.	826.	828.	827.
2nd Stage Est Reaction Temp, F	842.	839.	843.	843.	841.	841.	842.
Charge Pot Internal Temp, F	354.	361.	368.	353.	349.	349.	350.
Hot Separator Liquid Temp, F	623.	619.	620.	622.	627.	625.	619.
Unit Back Pressure, psig	2506.	2505.	2510.	2512.	2513.	2506.	2502.
Pretreater Coil DP, psi							
1st Stage Reactor DP, psi	6.2	5.9	5.9	5.9	5.9	5.9	6.3
1st Stage Internal Recycle Rate, cc/hr	47640.	47640.	47640.	47640.	47640.	47640.	47640.
2nd Stage Internal Recycle Rate, cc/hr	47640.	47640.	47640.	47640.	47640.	47640.	47640.
1st Stage Dry Coal SV, Lb Feed/Hr/Ft3	53.2	48.3	49.6	49.2	51.2	50.9	48.3
2nd Stage Dry coal SV, Lb Feed/Hr/Ft3	53.2	48.3	49.6	49.2	51.2	50.9	48.3
Two-Stage Space Velocity, Lb/Hr/Ft3	26.6	24.1	24.8	24.6	25.6	25.5	24.2
1st Stage Slurry Residence Time, min	33.0	36.4	35.5	35.5	34.4	34.6	35.1
2nd Stage Slurry Residence Time, min	32.8	36.2	35.2	35.2	34.0	34.2	34.8
Moisture in Coal, W%	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Total Dry Coal Fed to Date, gms	645140.	682255.	720362.	758182.	797544.	836682.	873822.
H2 Consumed--Meter, W% Dry Coal	7.2	7.6	7.3	7.5	7.2	7.4	7.8

AL: BLACK THUNDER MINE-POC-02 COAL (HRI 6213)

RIOD NUMBER	17	18	19	20	21	22	23	24
S YIELDS (Overheads), W% of mf coal								
	3.74	3.51	3.67	3.78	3.36	3.68	3.80	3.78
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.79	2.76	2.82	2.91	2.60	2.81	2.95	2.56
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3.25	3.39	3.37	3.44	2.98	3.20	3.43	3.00
	0.48	0.38	0.38	0.56	0.54	0.32	0.19	0.14
H10	0.99	1.14	1.05	1.05	0.89	0.95	1.06	0.99
H10	0.27	0.27	0.27	0.27	0.22	0.26	0.28	0.29
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H12	2.37	2.39	2.27	1.01	0.92	0.96	1.56	1.05
H12	0.90	0.97	0.92	0.29	0.28	0.27	0.34	0.32
YL-CYCLOPENTANE	0.55	0.51	0.45	0.50	0.48	0.43	0.46	0.48
OHEXANE	0.66	0.68	0.62	0.62	0.59	0.59	0.63	0.58
H14	0.45	0.41	0.46	0.34	0.33	0.38	0.41	0.38
7	0.90	0.64	0.58	0.63	0.60	0.65	0.64	0.60
	1.07	1.04	1.03	1.18	0.96	1.01	1.12	1.04
	3.21	3.03	2.74	4.11	2.89	3.31	3.54	3.44
	2.86	2.96	2.92	3.10	2.60	2.64	2.81	3.09

IOD NUMBER	17	18	19	20	21	22	23	24
YIELDS (Bottoms), W% of mf coal								
	0.11	0.10	0.12	0.11	0.11	0.12	0.10	0.10
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.27	0.23	0.28	0.28	0.27	0.29	0.26	0.21
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.64	0.50	0.63	0.67	0.61	0.66	0.63	0.48
	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01
H10	0.33	0.28	0.32	0.33	0.31	0.34	0.32	0.25
H10	0.08	0.06	0.07	0.08	0.07	0.07	0.07	0.07
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H12	0.17	0.16	0.17	0.17	0.15	0.17	0.16	0.14
H12	0.08	0.07	0.07	0.08	0.09	0.08	0.07	0.07
YL-CYCLOPENTANE	0.09	0.10	0.09	0.09	0.08	0.09	0.09	0.08
OHEXANE	0.14	0.16	0.14	0.13	0.11	0.15	0.14	0.12
H14	0.10	0.11	0.09	0.09	0.09	0.10	0.09	0.08
7	0.10	0.11	0.10	0.09	0.07	0.10	0.10	0.09
	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	0.15	0.15	0.14	0.16	0.16	0.18	0.14	0.11
	0.65	0.53	0.67	0.70	0.67	0.66	0.56	0.53

RUN 227-93 (POC PB-03) MATERIAL BALANCE

Coal Liquefaction using Dispersed Slurry Fe/Mo Catalysts

COAL: BLACK THUNDER MINE: POC-02 COAL (HRI-6213)

CATALYSTS: HTI'S Fe + MOLYVAN-A (to K-1)

od Number	24T	25T	26T	27T
(Start of Period)	03/26/96	03/27/96	03/28/96	03/29/96
tion, hrs	24.	24.	24.	24.
s of Run (End of Period)	576.	600.	624.	648.
TS, GRAMS				
Coal	44353.0	39584.0	43491.0	43385.0
Makeup Oil to Charge (L-885+L-883 or L-886)	23823.0	21262.0	23360.0	23303.0
Makeup Oil to Buffer (L-885+L-883 or L-886)	0.0	0.0	0.0	0.0
Pfl Recycled to Charge+K-2 Cat Addition	20530.0	18323.0	20131.0	20083.0
CAS Btms Recycled to Charge	0.0	0.0	0.0	0.0
Filter Cake Recycled to Charge	0.0	0.0	0.0	0.0
Pfl to Stage 1 Buffer	1020.0	940.0	613.0	824.0
Pfl to Stage 2 Buffer	714.0	566.0	625.0	636.0
Water to Hot Separators	4996.0	4900.0	4958.0	5003.0
Total Sulfur Added	1200.0	1200.0	1200.0	1200.0
Additive (Fe+Mo Catalysts)	644.0	575.0	631.0	630.0
H2 to 1st Stage	4627.2	4627.3	4627.5	4627.6
H2 to 2nd Stage	2028.8	2028.8	2028.8	2028.9
Hydrogen Bleed	696.5	696.6	696.6	696.6
TOTAL GRAMS IN	104632.5	94702.7	102361.9	102417.1
UTS, GRAMS				
Hydrogen Out	4499.9	4514.6	4572.7	4840.1
Total Gas Product (N2,H2 Free)	9696.0	9573.8	9321.2	6977.5
Unit Knockouts	522.0	503.0	569.0	604.0
Separator Overhead (HTU) Product	21202.0	20147.0	20867.0	21789.0
Atmospheric Overhead Product (Sample)	0.0	0.0	0.0	0.0
CAS Bottoms	66668.0	59304.0	64547.0	65593.0
Feed + Interstage Slurry Sample	124.0	82.0	1487.0	86.0
TOTAL GRAMS OUT	102711.8	94124.4	101363.9	99889.7
% Total Material Recovery (Gross)	98.16	99.39	99.03	97.53

AGC TLKL RHS DLT WFK VRP JH

od Number	24T	25T	26T	27T
-SEPARATOR BOTTOMS PRODUCT BREAKDOWN, GRAMS-----				
MOSPHERIC STILL				

CAS Vapor Outlet Temperature, deg-f	86.	88.	87.	87.
CAS Reboiler Temperature, deg-f	111.	111.	112.	112.
CAS Charge	66668.0	59304.0	64547.0	65593.0
CAS Overheads to HTU Feed Pot	0.0	0.0	0.0	0.0
****ASOH AND UNIT KNOCKOUTS ARE BEING FED TO THE HTU*****				
CAS Bottoms	66668.0	59304.0	64547.0	65593.0
ESSURE FILTER				

Pressure Filter Charge, gms	66344.0	58880.0	63780.0	65035.0
Pressure Filter Cake, gms	6505.0	7528.0	8283.0	9651.0
Pressure Filter Liquid, gms	58026.0	48979.0	53084.0	53851.0
Pressure Filter Loss, gms	1813.0	2373.0	2413.0	1533.0
W% Pfs	9.80	12.79	12.99	14.84

od Number	24T	25T	26T	27T
-CHARGE, PRODUCT, AND RECYCLE RATES-----				
ED RATES, GRAMS/HOUR				
Total Coal Feed	1848.0	1649.3	1812.1	1807.7
Dry Coal Feed	1663.2	1484.4	1630.9	1626.9
Total Makeup Oil Rate	992.6	885.9	973.3	971.0
Water to Hot Separator	208.2	204.2	206.6	208.5
H2 to 1st Stage	192.8	192.8	192.8	192.8
H2 to 2nd Stage	84.5	84.5	84.5	84.5
CYCLE RATES TO REACTOR, GRAMS/HOUR				
PFL Recycled to Slurry + Pretreater Buffer	855.4	763.5	838.8	836.8
CAS Bottoms Recycled	0.0	0.0	0.0	0.0
Pfl to 1st Stage Buffer	42.5	39.2	25.5	34.3
Pfl to 2nd Stage Buffer	29.8	23.6	26.0	26.5
T COLLECTED PRODUCTS (INCLUDING SAMPLES), GRAMS/HOUR				
Total Gas (incl. N2)	638.1	628.4	643.2	537.3
(N2 free)	591.5	587.0	578.9	492.4
SOH	463.4	441.6	439.5	471.2
SOH-H2O	420.0	397.9	430.0	436.7
SOH-NET WATER	211.9	193.7	223.4	228.3
Knockouts	21.8	21.0	23.7	25.2
Filter Cake	271.0	313.7	345.1	402.1
Filter Liquid	1565.6	1313.5	1422.0	1410.0
Asoh + KO	21.8	21.0	23.7	25.2
Total CAS Bottoms	2777.8	2471.0	2689.5	2733.0
Reactor 1 Liquid Sample	5.2	3.4	62.0	3.6
Separator Bottoms to CAS	2777.8	2471.0	2689.5	2733.0
Total Asoh	21.8	21.0	23.7	25.2
CAS Bottoms to Pressure Filter	2764.3	2453.3	2657.5	2709.8
Total Filter Cake	271.0	313.7	345.1	402.1
Total Filter Liquid	2493.3	2139.7	2312.4	2307.7

od number	24T	25T	26T	27T
-GAS RATES:-----				
H2 to 1st Stage, scfh	40.0	40.0	40.0	40.1
H2 to 1st Stage Recycle, scfh	40.0	40.0	40.0	40.0
H2 to 2nd Stage, scfh	35.1	35.1	35.1	35.1
Bleed H2, scfh	12.1	12.1	12.1	12.1
Vent Gas, scfh (incl. N2)	89.3	89.3	90.9	92.1
(N2-Free)	87.9	88.0	88.9	90.8
-NET ADJ. PRODUCTS, W% DRY COAL -----				
Total CO + CO2	4.60	5.17	4.32	3.96
Total C1-C3	10.13	10.96	10.76	6.73
Total C4-C7	5.94	6.75	5.19	4.45
SOH TOTAL H2O	25.25	26.80	26.36	26.84
SOH NET WATER	12.74	13.05	28.00	14.03
SOH Distillate Oil	27.86	29.75	26.95	28.96
Asoh + KO	1.31	1.41	1.45	1.55
Pfl	94.86	89.52	88.90	87.89
Pfs	16.38	21.28	21.42	24.93
CAS Bottoms	0.00	0.00	0.00	0.00
Reactor 1 Liquid Sample	0.31	0.23	3.80	0.22
-OPERATING CONDITIONS-----				
Pretreater Coil Temp, F				
1st Stage Est Reaction Temp, F	828.	830.	826.	826.
2nd Stage Est Reaction Temp, F	842.	843.	842.	841.
Charge Pot Internal Temp, F	350.	348.	350.	351.
Hot Separator Liquid Temp, F	636.	629.	630.	631.
Unit Back Pressure, psig	2504.	2507.	2507.	2512.
Pretreater Coil DP, psi				
1st Stage Reactor DP, psi	6.1	5.7	5.9	5.5
1st Stage Internal Recycle Rate, cc/hr	47640.	47640.	47640.	47640.
2nd Stage Internal Recycle Rate, cc/hr	47640.	47640.	47640.	47640.
1st Stage Dry Coal SV, Lb Feed/Hr/Ft3	51.9	46.3	50.9	50.8
2nd Stage Dry coal SV, Lb Feed/Hr/Ft3	51.9	46.3	50.9	50.8
Two-Stage Space Velocity, Lb/Hr/Ft3	26.0	23.2	25.5	25.4
1st Stage Slurry Residence Time, min	33.8	37.8	34.6	34.6
2nd Stage Slurry Residence Time, min	33.5	37.5	34.3	34.3
Moisture in Coal, W%	10.00	10.00	10.00	10.00
Total Dry Coal Fed to Date, gms	913740.	949365.	988507.	1027554.
H2 Consumed--Meter, W% Dry Coal	7.1	8.0	7.1	6.4

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RUN 227-93 (POC PB-03) MATERIAL BALANCE

Coal Liquefaction using Dispersed Slurry Fe/Mo Catalysts

COAL: BLACK THUNDER MINE: POC-02 COAL (HRI-6213)

CATALYSTS: HTI'S Fe + MOLYVAN-A (to K-1)

d Number	28T	29T	30T	31T	32T
(Start of Period)	03/30/96	03/31/96	04/01/96	04/02/96	04/03/96
ion, hrs	24.	24.	24.	24.	24.
of Run (End of Period)	672.	696.	720.	744.	768.
S, GRAMS					
oal	41071.0	42691.0	45663.0	42896.0	40059.0
akeup Oil to Charge (L-885+L-883 or L-886)	22060.0	22930.0	24526.0	23040.0	21517.0
akeup Oil to Buffer (L-885+L-883 or L-886)	0.0	0.0	0.0	1056.0	0.0
f1 Recycled to Charge+K-2 Cat Addition	19011.0	19719.0	21136.0	19856.0	18542.0
AS Btms Recycled to Charge	0.0	0.0	0.0	0.0	0.0
ilter Cake Recycled to Charge	0.0	0.0	0.0	0.0	0.0
f1 to Stage 1 Buffer	803.0	931.0	921.0	711.0	866.0
f1 to Stage 2 Buffer	377.0	930.0	650.0	720.0	720.0
ater to Hot Separators	4914.0	5185.0	5082.0	4967.0	4686.0
otal Sulfur Added	1200.0	1200.0	1200.0	1200.0	1200.0
dditive (Fe+Mo Catalysts)	596.0	620.0	663.0	621.0	582.0
2 to 1st Stage	4627.8	4626.9	4627.3	4627.3	4627.1
2 to 2nd Stage	2028.9	2028.8	2028.8	2028.8	2028.8
ydrogen Bleed	696.6	696.5	696.5	696.5	696.5
OTAL GRAMS IN	97385.3	101558.2	107193.5	102419.6	95524.4
TS, GRAMS					
ydrogen Out	4566.7	4655.9	4386.1	4485.9	4611.6
otal Gas Product (N2,H2 Free)	12179.2	9479.5	13375.1	11057.5	10823.5
nit Knockouts	502.0	579.0	664.0	714.0	588.0
eparator Overhead (HTU) Product	21125.0	20655.0	22660.0	24973.0	24023.0
tmospheric Overhead Product (Sample)	0.0	0.0	0.0	0.0	0.0
AS Bottoms	60506.0	62858.0	65564.0	57803.0	53651.0
eed + Interstage Slurry Sample	101.0	980.0	58.0	71.0	811.0
OTAL GRAMS OUT	98979.9	99207.4	106707.1	99104.5	94508.1
Total Material Recovery (Gross)	101.64	97.69	99.55	96.76	98.94

GC TLKL RHS DLT WFK VRP JH

d Number	28T	29T	30T	31T	32T
SEPARATOR BOTTOMS PRODUCT BREAKDOWN, GRAMS-----					
OSPHERIC STILL					

AS Vapor Outlet Temperature, deg-f	90.	91.	90.	89.	90.
AS Reboiler Temperature, deg-f	111.	113.	113.	114.	114.
AS Charge	60506.0	62858.0	65564.0	57803.0	53651.0
AS Overheads to HTU Feed Pot	0.0	0.0	0.0	0.0	0.0
****ASOH AND UNIT KNOCKOUTS ARE BEING FED TO THE HTU*****					
AS Bottoms	60506.0	62858.0	65564.0	57803.0	53651.0
SSURE FILTER					
---					
ressure Filter Charge, gms	60157.0	62058.0	65201.0	57472.0	52915.0
ressure Filter Cake, gms	9491.0	9741.0	8635.0	7714.0	7167.0
ressure Filter Liquid, gms	48502.0	50038.0	53956.0	47376.0	43432.0
ressure Filter Loss, gms	2164.0	2279.0	2610.0	2382.0	2316.0
% Pfs	15.78	15.70	13.24	13.42	13.54

d Number	28T	29T	30T	31T	32T
-CHARGE, PRODUCT, AND RECYCLE RATES-----					
D RATES, GRAMS/HOUR					
otal Coal Feed	1711.3	1778.8	1902.6	1787.3	1669.1
ry Coal Feed	1540.2	1600.9	1712.4	1608.6	1502.2
otal Makeup Oil Rate	919.2	955.4	1021.9	1004.0	896.5
ater to Hot Separator	204.8	216.0	211.8	207.0	195.3
2 to 1st Stage	192.8	192.8	192.8	192.8	192.8
2 to 2nd Stage	84.5	84.5	84.5	84.5	84.5
YCLE RATES TO REACTOR, GRAMS/HOUR					
FL Recycled to Slurry + Pretreater Buffer	792.1	821.6	880.7	827.3	772.6
AS Bottoms Recycled	0.0	0.0	0.0	0.0	0.0
fl to 1st Stage Buffer	33.5	38.8	38.4	29.6	36.1
fl to 2nd Stage Buffer	15.7	38.8	27.1	30.0	30.0
COLLECTED PRODUCTS (INCLUDING SAMPLES), GRAMS/HOUR					
otal Gas (incl. N2)	738.2	653.6	788.5	704.7	699.2
(N2 free)	697.7	589.0	740.0	647.6	643.1
OH	478.5	473.0	516.6	603.9	591.0
SOH-H2O	401.7	387.6	427.5	436.6	410.0
OH-NET WATER	196.9	171.6	215.8	229.7	214.7
Knockouts	20.9	24.1	27.7	29.8	24.5
ilter Cake	395.5	405.9	359.8	321.4	298.6
ilter Liquid	1269.8	1280.7	1410.8	1186.3	1067.5
soh + KO	20.9	24.1	27.7	29.8	24.5
otal CAS Bottoms	2521.1	2619.1	2731.8	2408.5	2235.5
eactor 1 Liquid Sample	4.2	40.8	2.4	3.0	33.8
eparator Bottoms to CAS	2521.1	2619.1	2731.8	2408.5	2235.5
otal Asoh	20.9	24.1	27.7	29.8	24.5
AS Bottoms to Pressure Filter	2506.5	2585.8	2716.7	2394.7	2204.8
otal Filter Cake	395.5	405.9	359.8	321.4	298.6
otal Filter Liquid	2111.1	2179.9	2356.9	2073.3	1906.2

ɔd number	28T	29T	30T	31T	32T
-GAS RATES:-----					
H2 to 1st Stage, scfh	40.1	40.0	40.0	40.0	40.0
H2 to 1st Stage Recycle, scfh	40.0	40.0	40.0	40.0	40.0
H2 to 2nd Stage, scfh	35.1	35.1	35.1	35.1	35.1
Bleed H2, scfh	12.1	12.1	12.1	12.1	12.1
Vent Gas, scfh (incl. N2)	92.2	92.5	91.1	90.8	92.7
(N2-Free)	91.0	90.6	89.7	89.1	91.0
-NET ADJ. PRODUCTS, W% DRY COAL -----					
Total CO + CO2	10.01	4.48	7.98	4.75	4.69
Total C1-C3	11.36	11.15	13.55	12.38	13.28
Total C4-C7	7.20	5.37	7.23	7.55	7.79
SOH TOTAL H2O	26.08	24.21	24.97	27.14	27.29
SOH NET WATER	12.79	28.00	12.60	14.28	28.00
SOH Distillate Oil	31.07	29.55	30.17	37.54	39.34
Asoh + KO	1.36	1.51	1.62	1.85	1.63
Pfl	83.24	81.75	83.15	74.49	72.83
Pfs	25.83	25.68	21.13	20.10	20.16
CAS Bottoms	0.00	0.00	0.00	0.00	0.00
Reactor 1 Liquid Sample	0.27	2.55	0.14	0.18	2.25
-OPERATING CONDITIONS-----					
Pretreater Coil Temp, F					
1st Stage Est Reaction Temp, F	829.	828.	837.	842.	842.
2nd Stage Est Reaction Temp, F	842.	842.	851.	860.	860.
Charge Pot Internal Temp, F	354.	353.	351.	349.	343.
Hot Separator Liquid Temp, F	631.	629.	630.	629.	628.
Unit Back Pressure, psig	2513.	2501.	2503.	2500.	2502.
Pretreater Coil DP, psi					
1st Stage Reactor DP, psi	5.4	5.5	5.7	5.6	5.8
1st Stage Internal Recycle Rate, cc/hr	47640.	47640.	51610.	55580.	55580.
2nd Stage Internal Recycle Rate, cc/hr	47640.	47640.	47640.	47640.	47640.
1st Stage Dry Coal SV, Lb Feed/Hr/Ft3	48.1	50.0	53.4	50.2	46.9
2nd Stage Dry coal SV, Lb Feed/Hr/Ft3	48.1	50.0	53.4	50.2	46.9
Two-Stage Space Velocity, Lb/Hr/Ft3	24.0	25.0	26.7	25.1	23.4
1st Stage Slurry Residence Time, min	36.5	35.1	32.8	34.6	37.4
2nd Stage Slurry Residence Time, min	36.4	34.7	32.6	34.3	37.1
Moisture in Coal, W%	10.00	10.00	10.00	10.00	10.00
Total Dry Coal Fed to Date, gms	1064518.	1102940.	1144036.	1182643.	1218696.
H2 Consumed--Meter, W% Dry Coal	7.5	7.0	7.2	7.4	7.6

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: BLACK THUNDER MINE-POC-02 COAL (HRI 6213)

OD NUMBER	25	26	27	28	29	30	31	32
YIELDS (Overheads), W% of mf coal								
	4.24	3.55	2.45	4.21	3.68	5.01	4.68	4.84
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.76	3.85	1.58	2.98	4.00	3.43	3.00	3.35
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3.15	2.63	1.92	3.38	2.72	3.83	3.61	3.89
	0.32	0.15	0.37	0.04	0.15	0.52	0.30	0.36
10	1.03	0.87	0.65	1.13	0.90	1.23	1.15	1.25
10	0.33	0.26	0.23	0.38	0.27	0.40	0.38	0.42
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	1.07	0.89	0.76	0.78	0.92	1.07	1.52	1.19
12	0.36	0.23	0.24	0.31	0.24	0.36	0.57	0.41
L-CYCLOPENTANE	0.54	0.54	0.33	0.66	0.57	0.47	0.50	0.54
HEXANE	0.71	0.65	0.44	0.84	0.68	0.63	0.61	0.73
14	0.43	0.39	0.23	0.43	0.41	0.37	0.34	0.43
	0.73	0.00	0.00	1.23	0.00	0.59	0.62	0.74
	1.17	1.05	0.68	1.24	1.09	1.16	1.27	1.15
	3.82	3.13	3.10	8.58	3.25	6.64	3.37	3.38
	3.39	2.99	2.13	3.78	3.11	3.10	3.27	3.52

OD NUMBER	25	26	27	28	29	30	31	32
YIELDS (Bottoms), W% of mf coal								
	0.11	0.09	0.10	0.10	0.09	0.14	0.11	0.13
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.23	0.18	0.21	0.22	0.19	0.34	0.28	0.31
	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01
	0.47	0.45	0.45	0.46	0.46	0.78	0.71	0.76
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
10	0.25	0.24	0.25	0.25	0.25	0.43	0.41	0.42
10	0.07	0.07	0.07	0.07	0.07	0.12	0.11	0.11
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.15	0.14	0.14	0.15	0.14	0.22	0.21	0.23
12	0.08	0.07	0.08	0.08	0.07	0.12	0.11	0.12
L-CYCLOPENTANE	0.09	0.08	0.10	0.10	0.08	0.10	0.10	0.11
HEXANE	0.14	0.13	0.14	0.16	0.13	0.15	0.15	0.18
14	0.10	0.08	0.10	0.10	0.09	0.11	0.11	0.12
	0.11	0.09	0.12	0.13	0.10	0.11	0.11	0.13
	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.02
	0.15	0.12	0.16	0.16	0.12	0.16	0.09	0.14
	0.60	0.56	0.61	0.60	0.58	0.69	0.68	0.74

DETAILED GAS NORMALIZED YIELDS

RIOD NUMBER	5	8	11	15
RIOD START	03/07/96	03/10/96	03/13/96	03/17/96
MALIZED YIELDS, W% DRY FRESH FEED				
C1	3.89	3.23	3.07	3.17
C2	2.65	2.75	2.63	2.99
C3	1.66	4.44	4.18	3.39
C4	3.22	1.66	1.70	1.75
C5	0.90	0.88	0.81	2.05
C6-C7	0.70	0.59	0.75	1.94
MALIZED YIELDS, W% MAF BASIS				
C1-C3	8.70	11.06	10.48	10.13
C4-C7	5.11	3.32	3.46	6.08

DETAILED GAS NORMALIZED YIELDS

IOD NUMBER	19	22	26	29	32
IOD START	03/21/96	03/24/96	03/28/96	03/31/96	04/03/96
ALIZED YIELDS, W% DRY FRESH FEED					
1	3.54	3.60	3.48	3.59	
2	2.90	2.95	3.86	3.99	
3	3.75	3.67	2.95	3.04	
4	1.97	1.86	1.52	1.57	
5	3.21	1.40	1.27	1.31	
6-C7	2.58	2.58	2.16	2.23	
ALIZED YIELDS, W% MAF BASIS					
1-C3	10.81	10.85	10.91	11.27	
4-C7	8.23	6.20	5.26	5.42	